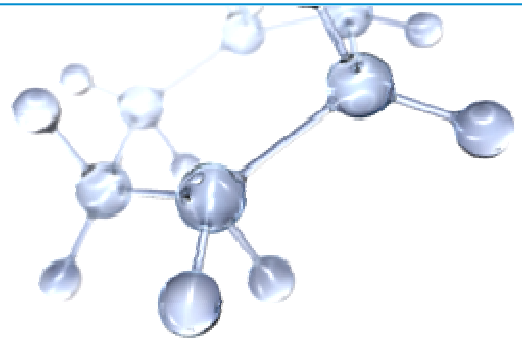
ExxonMobil

Taking on the world's toughest energy challenges.™

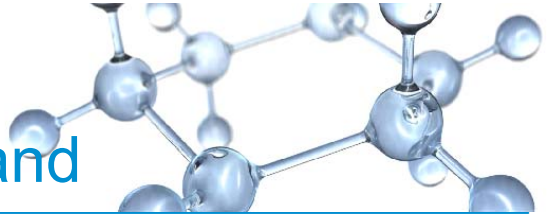


The Role of Technology in Energy Outlook

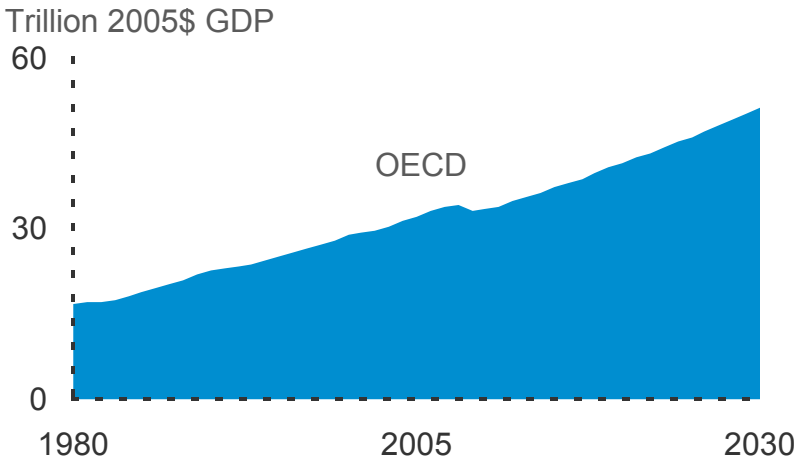
Nazeer Bhore
Senior Technology Advisor
Corporate Strategic Planning

June 8, 2010
The CO2 Summit: Technology and Opportunity

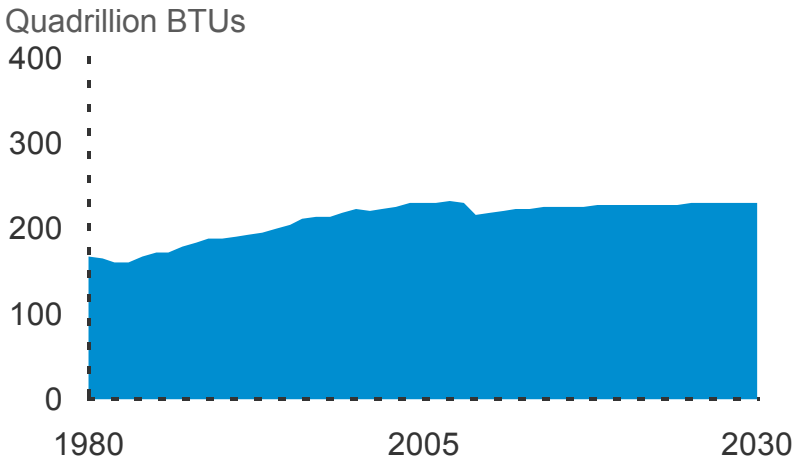
Economic Growth Drives Energy Demand

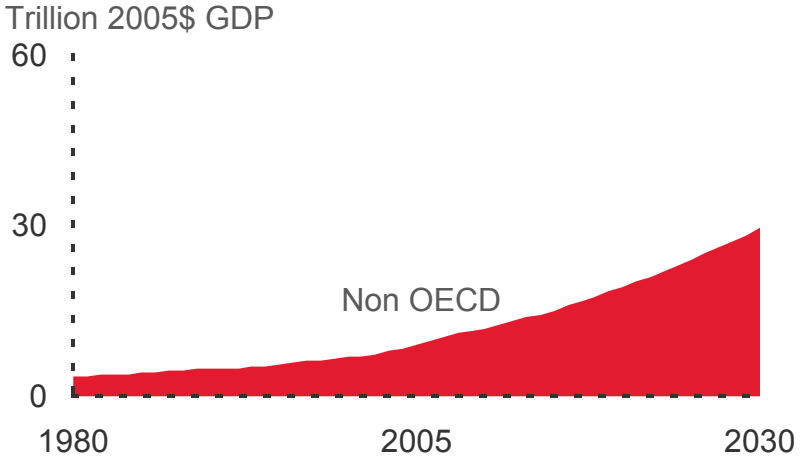


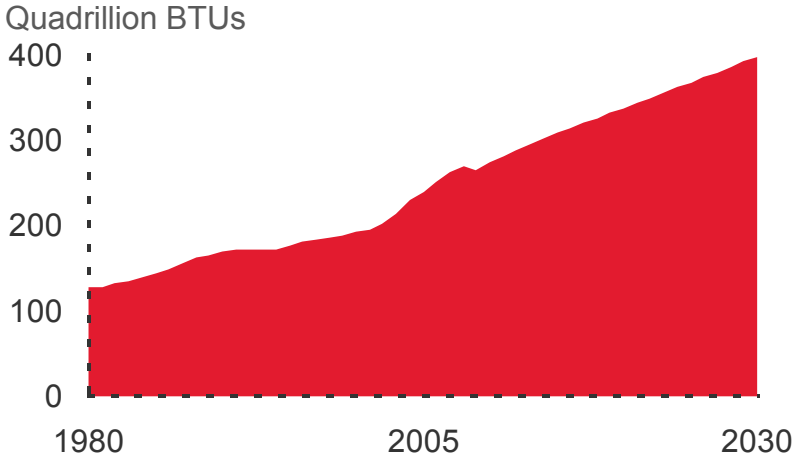
GDP



Demand

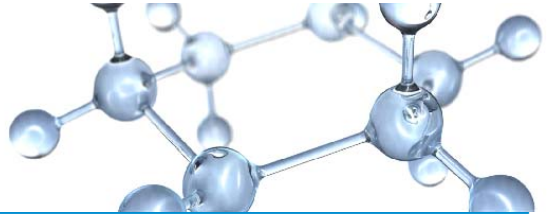






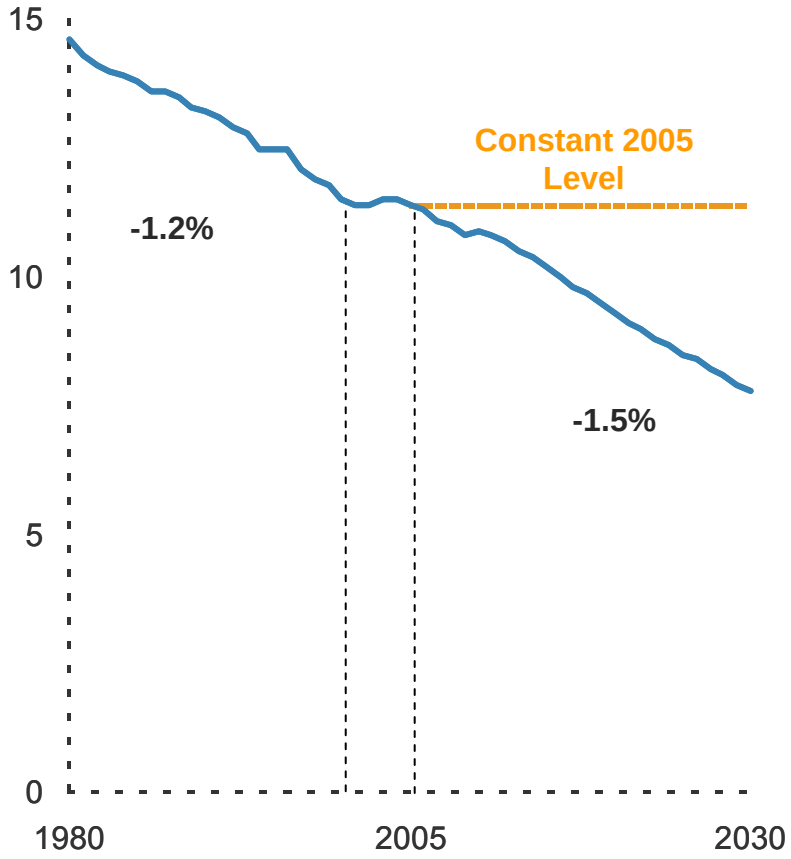
ExxonMobil
Taking on the world's toughest energy challenges.™

Efficiency: Reducing Demand Growth



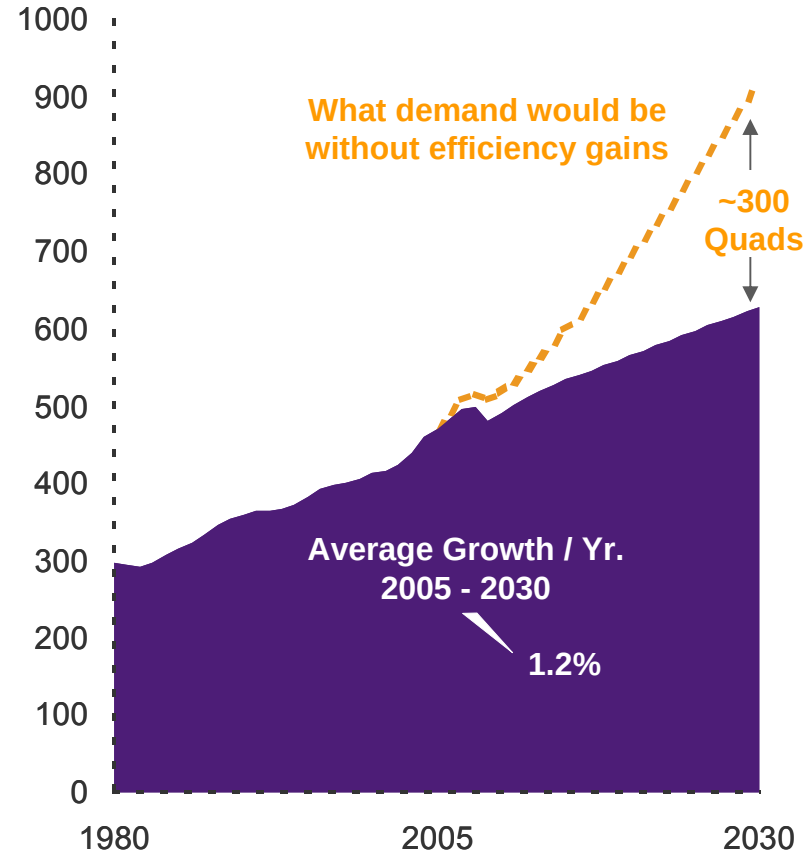
Energy per GDP

MBTU / 2005$ k GDP



Demand

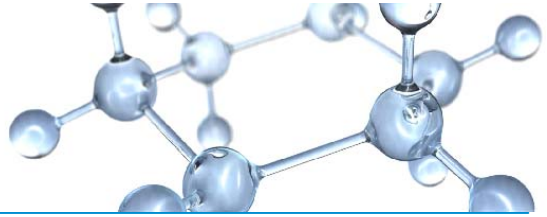
Quadrillion BTUs



ExxonMobil

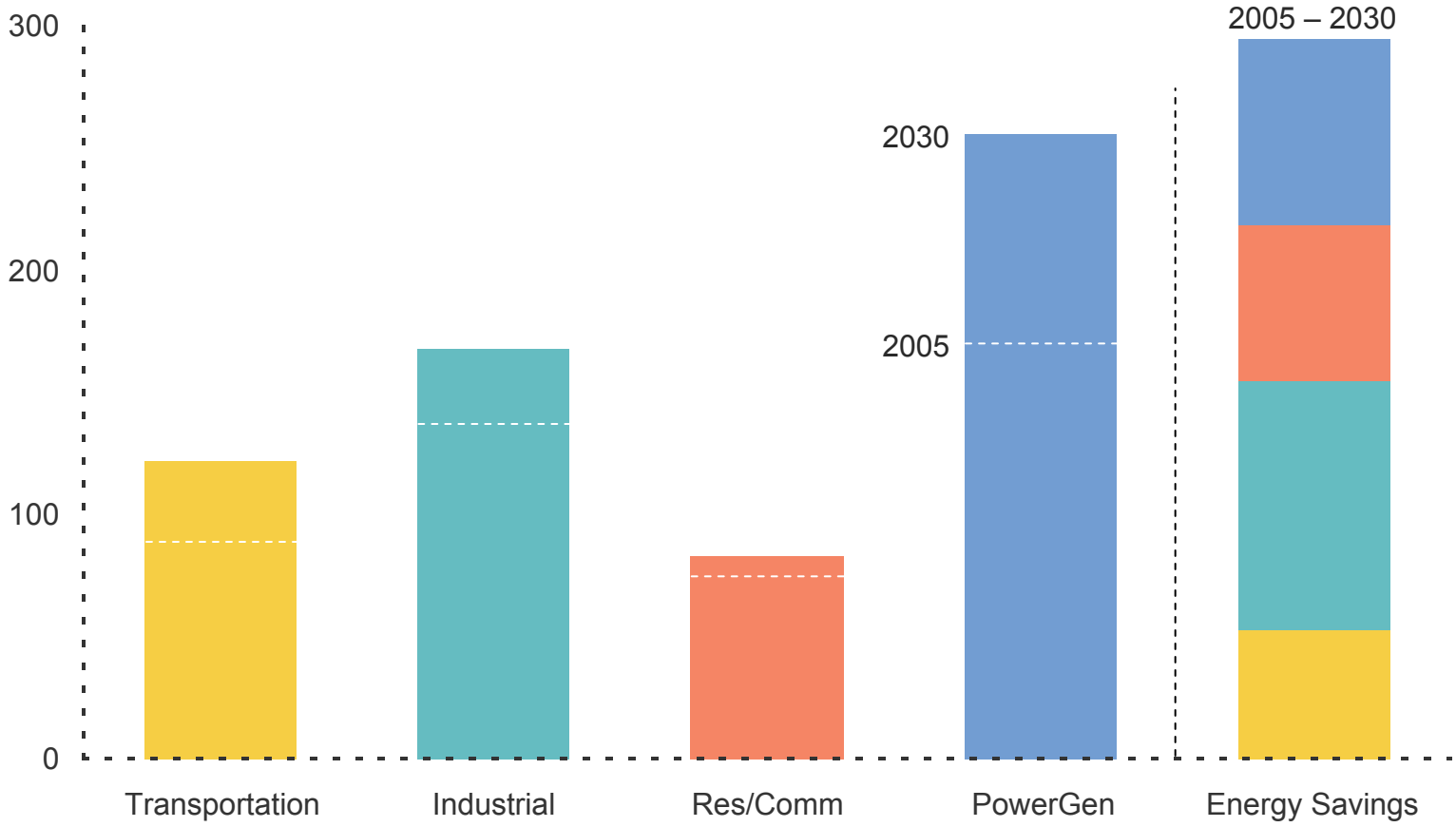
Taking on the world's toughest energy challenges.™

Growing Global Demand



By Sector

Quadrillion BTUs

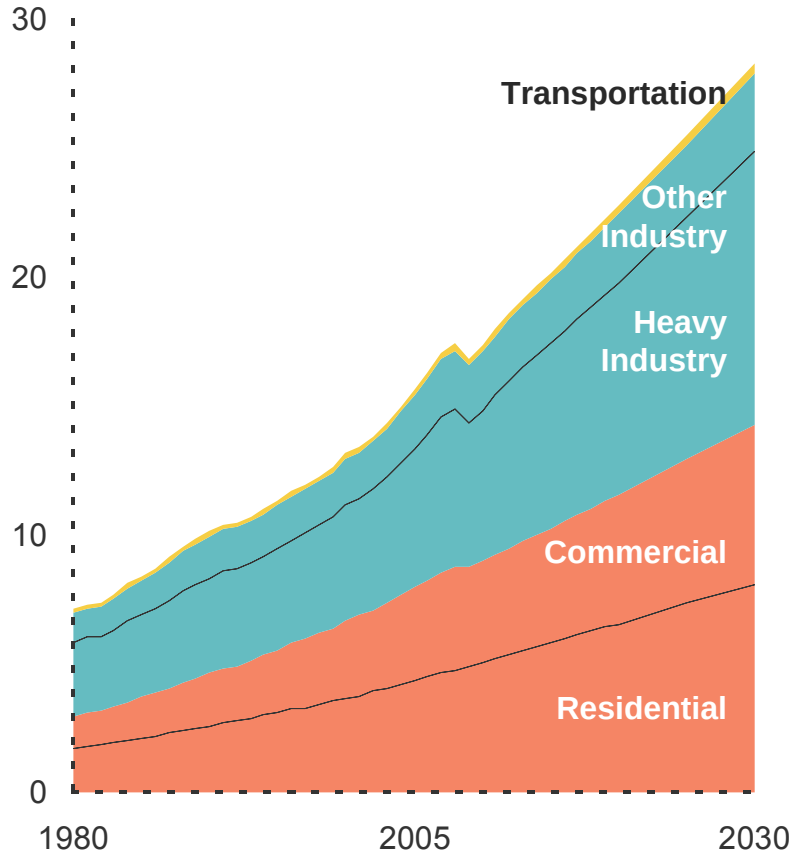


ExxonMobil
Taking on the world's toughest energy challenges.™

Electricity Use is Growing Fast

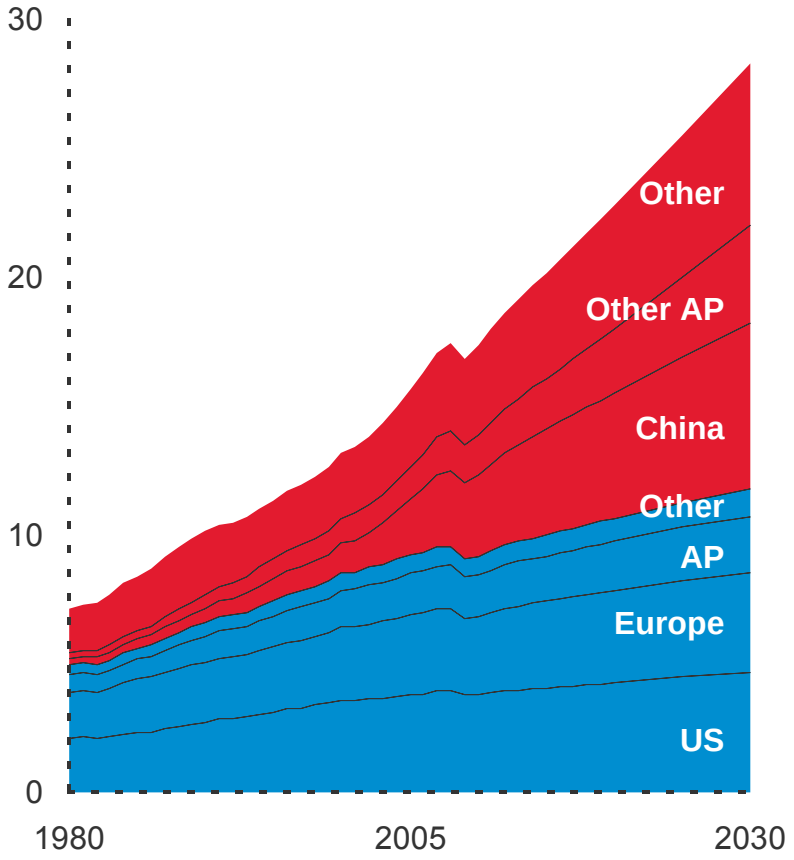
By Sector

k TWhr



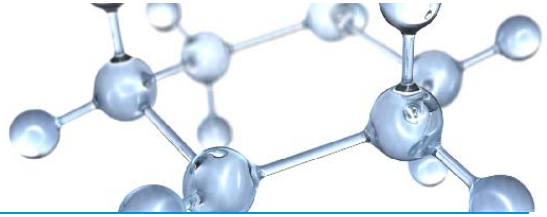
By Region

k TWhr



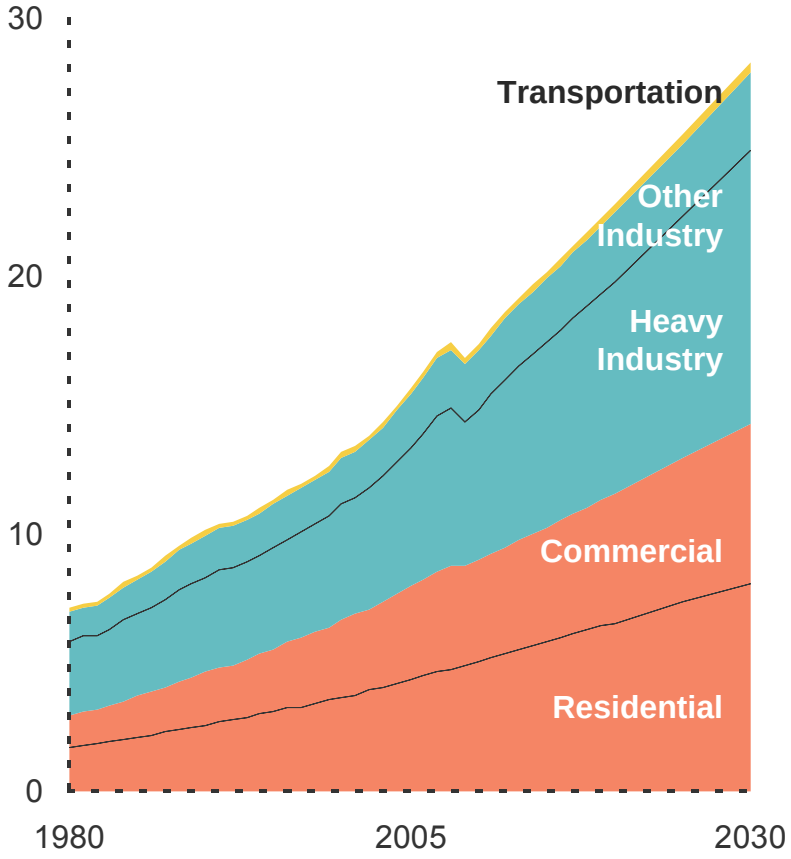
ExxonMobil
Taking on the world's toughest energy challenges.™

Electricity Use is Growing Fast



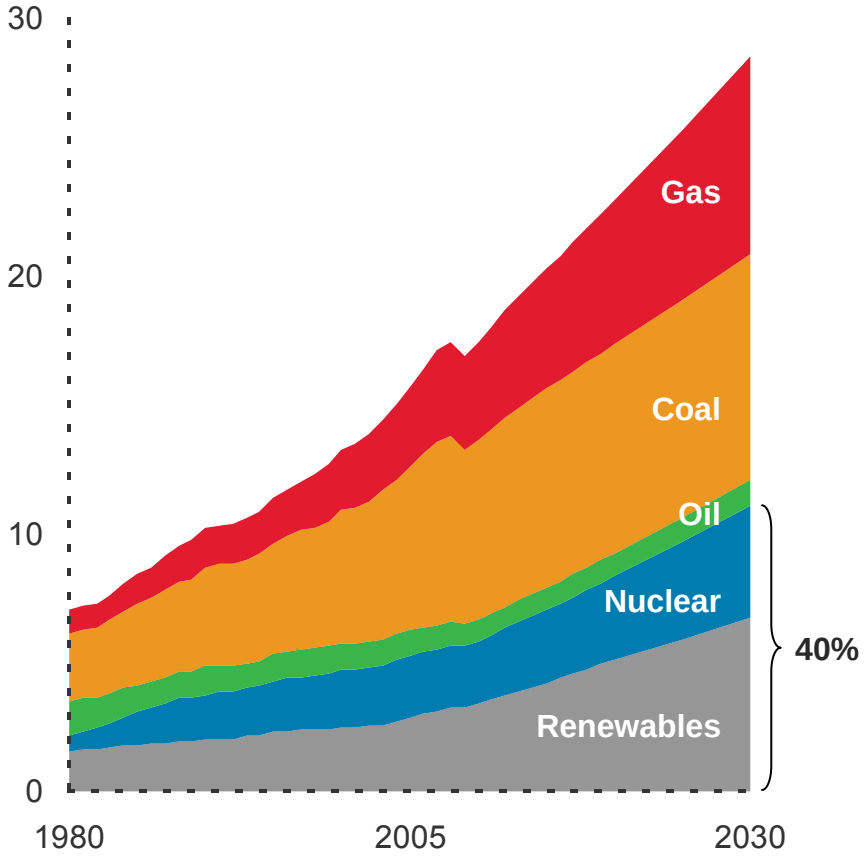
By Sector

k TWhr



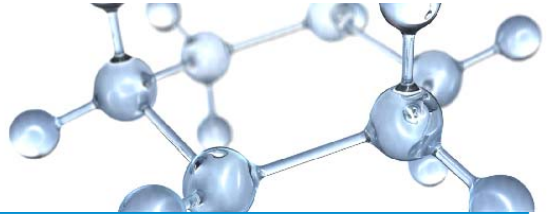
By Generation

k TWhr



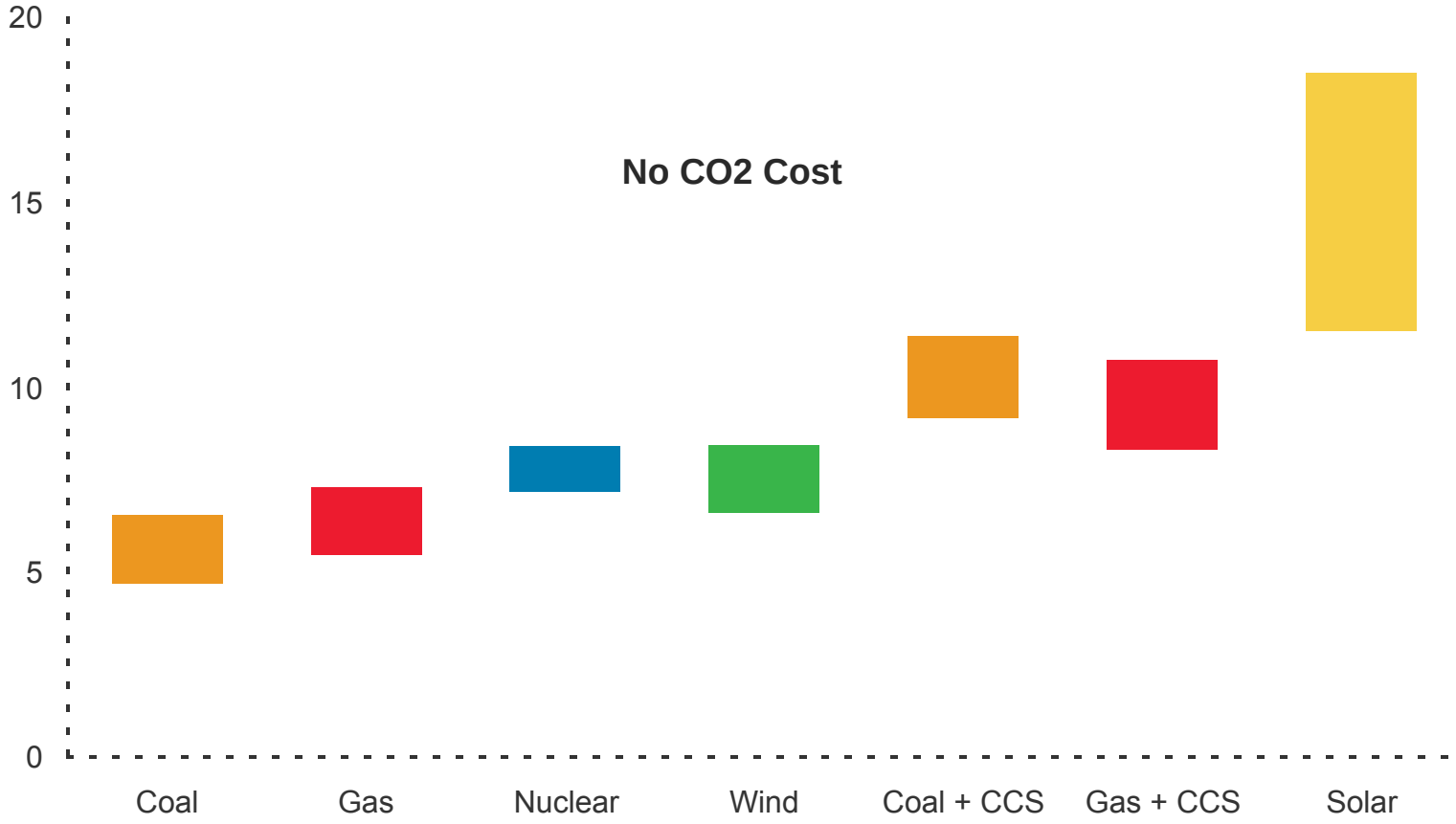
ExxonMobil
Taking on the world's toughest energy challenges.™

Electricity Generation Cost

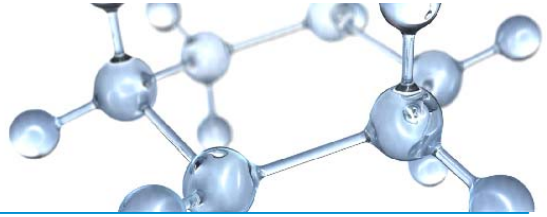


US Baseload, Startup 2025

2009 Cents/kWhr

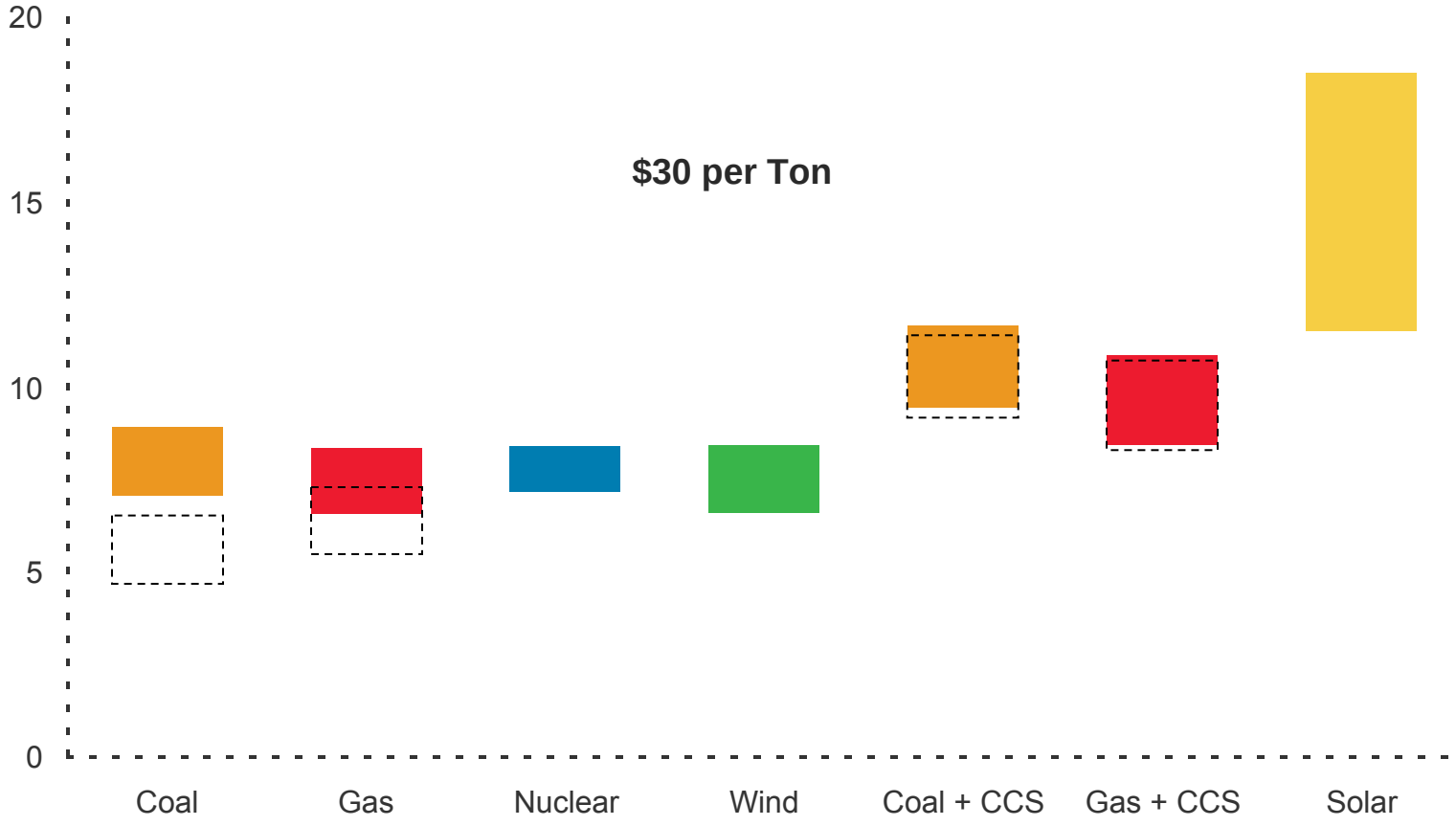


Electricity Generation Cost

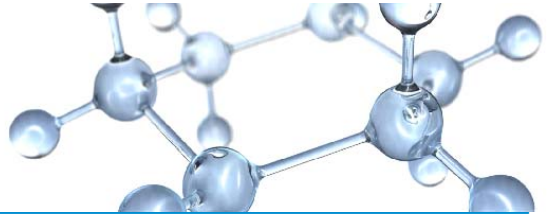


US Baseload, Startup 2025

2009 Cents/kWhr

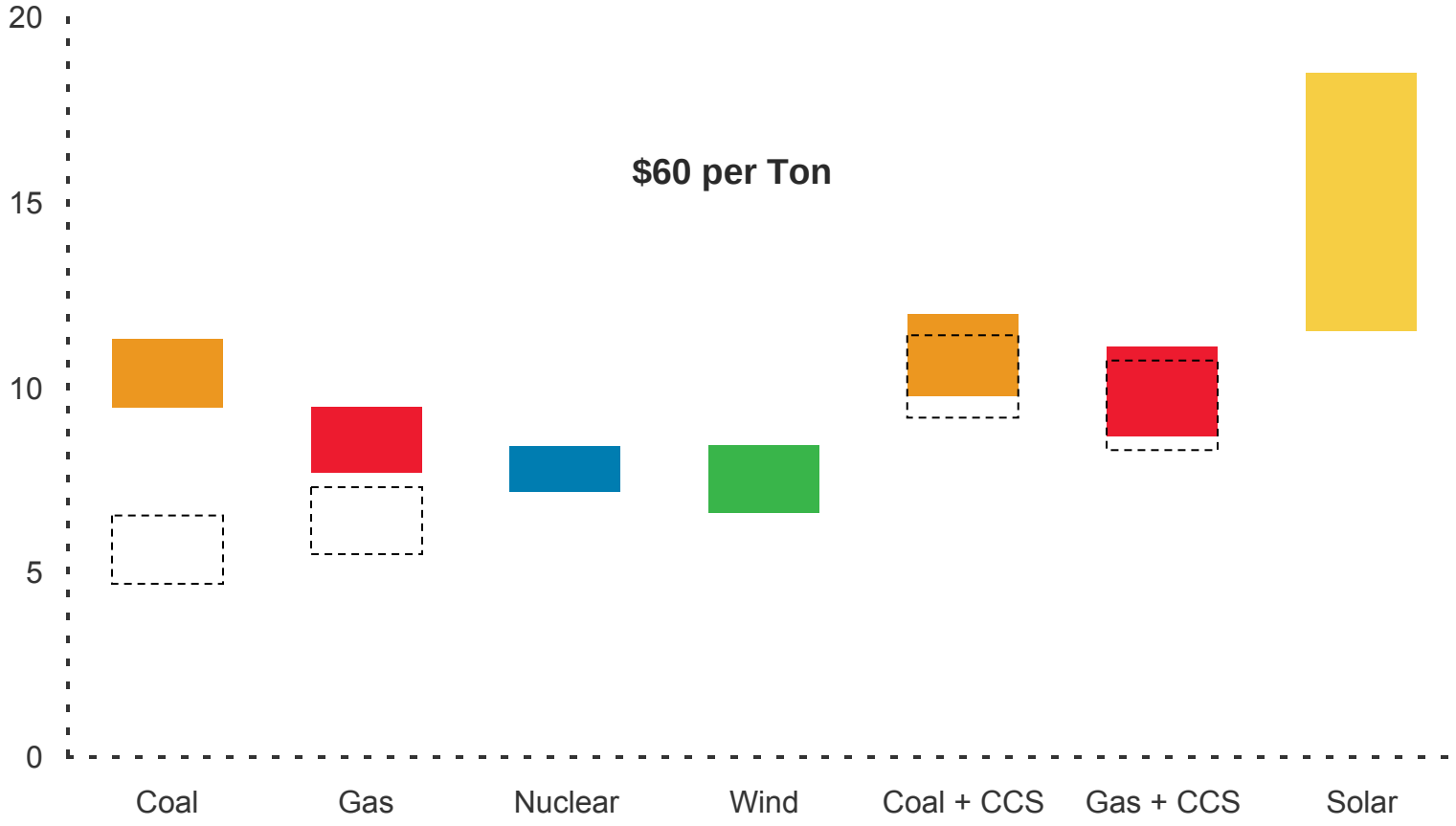


Electricity Generation Cost



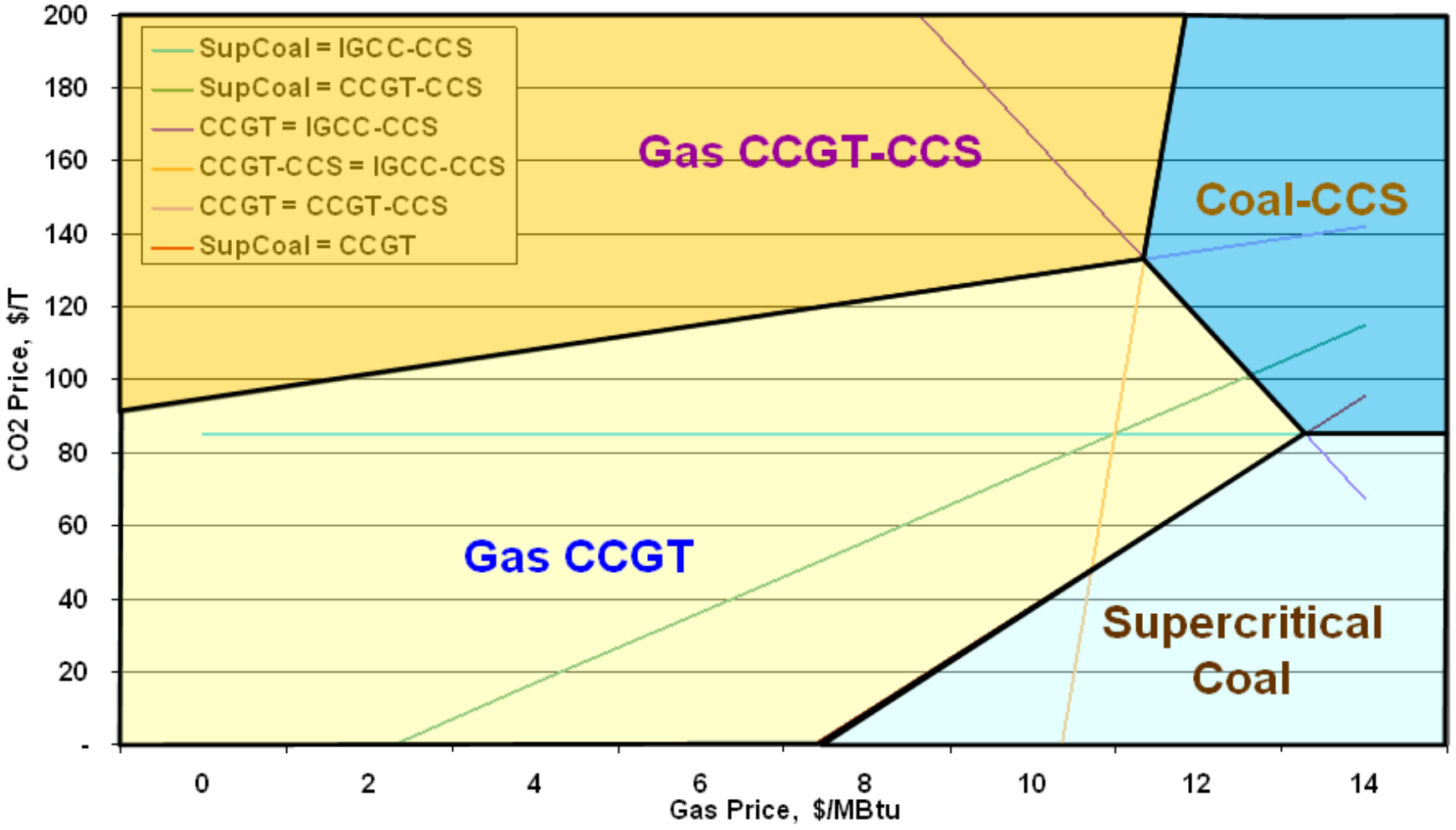
US Baseload, Startup 2025

2009 Cents/kWhr



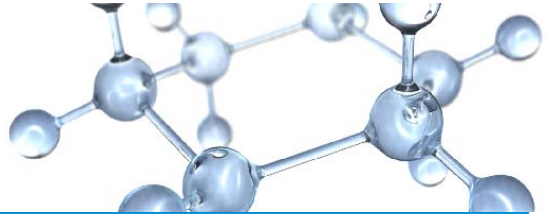
Generation Alternative Preferences

- Preferred (lowest cost) generation alternative depends on gas and CO2 price views (shown for U.S.)
  - Preference zones will shift with technology, coal prices, economic parameters



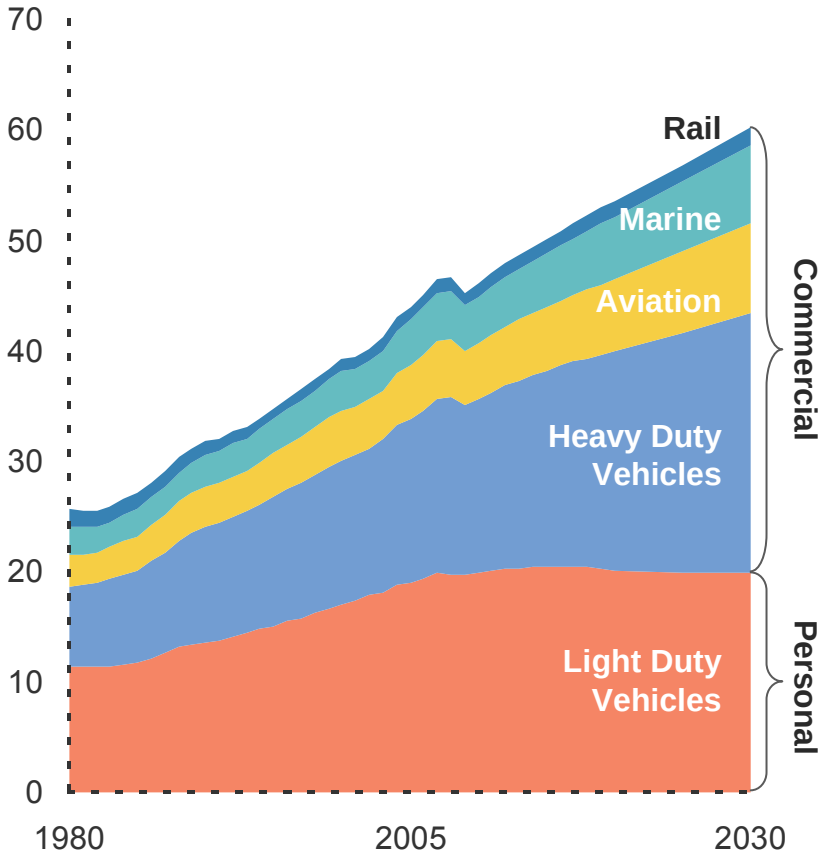
Assuming baseload utilization, 2015 startup, coal price $2.50/MBtu

Global Transportation Demand



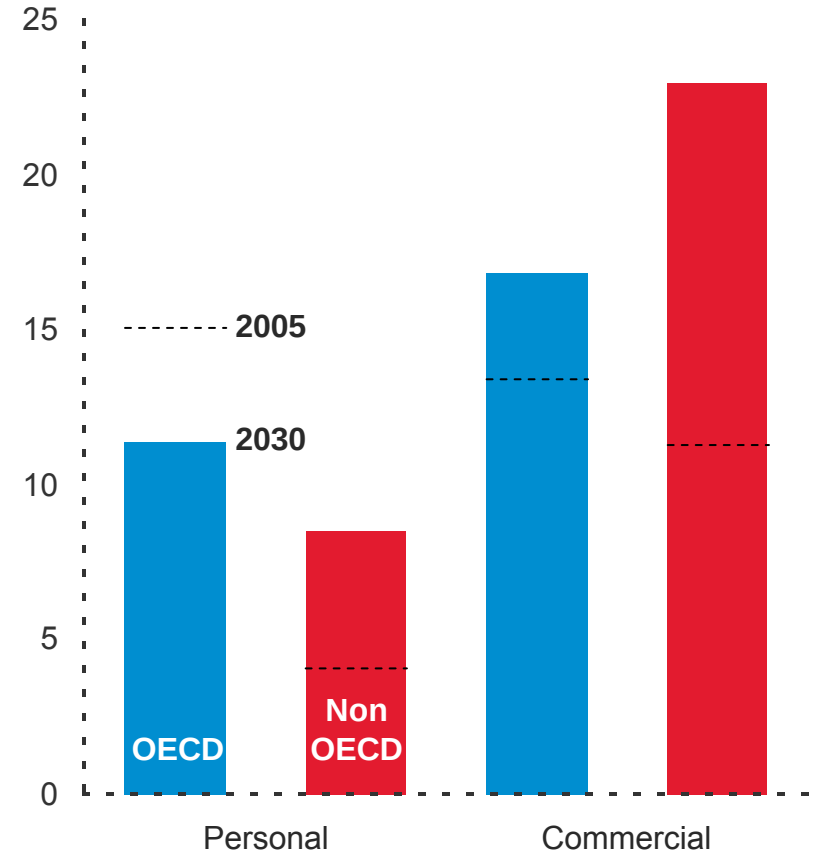
By Sector

MBDOE



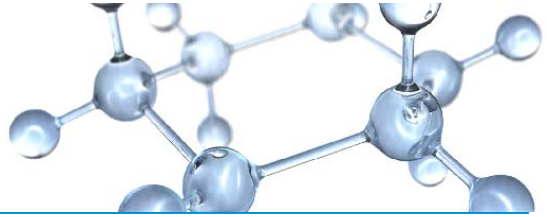
Personal vs. Commercial

MBDOE



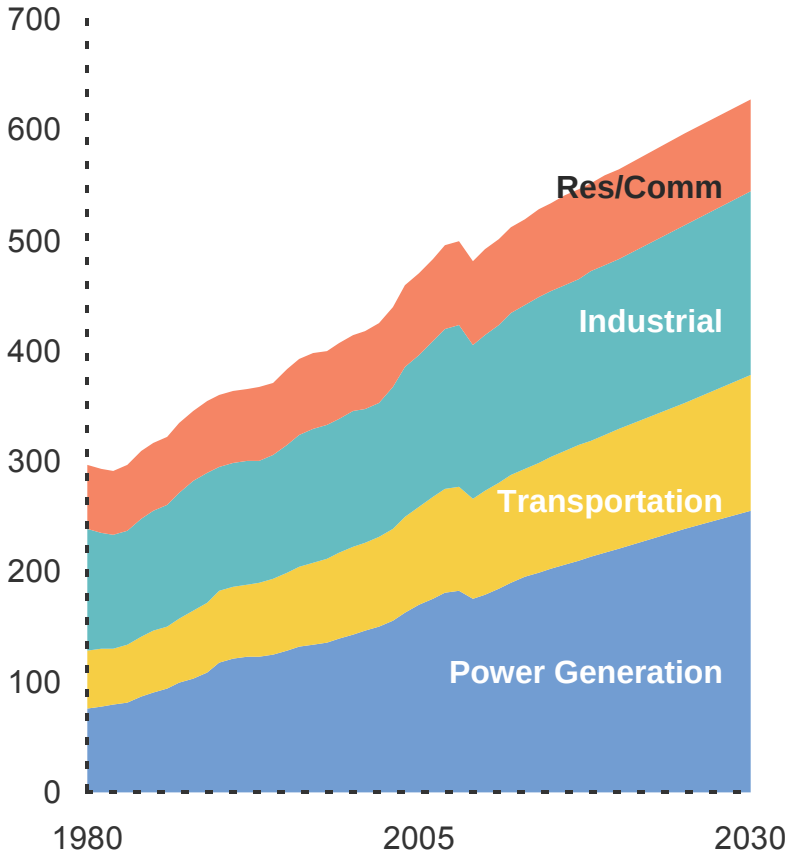
ExxonMobil
Taking on the world's toughest energy challenges.™

Global Energy Demand and Supply



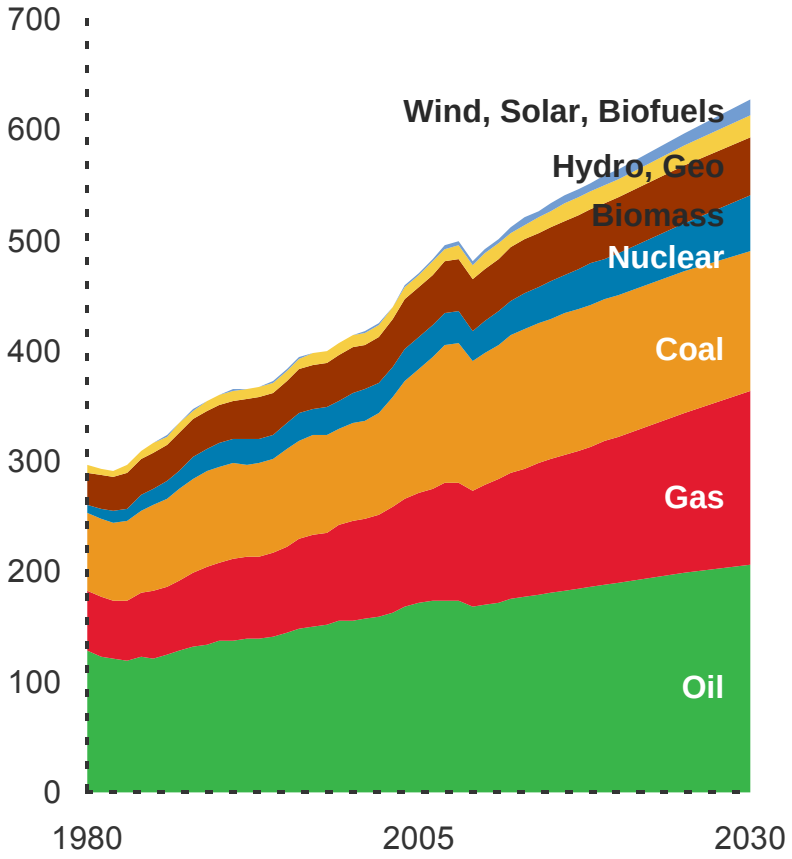
By Sector

Quadrillion BTUs



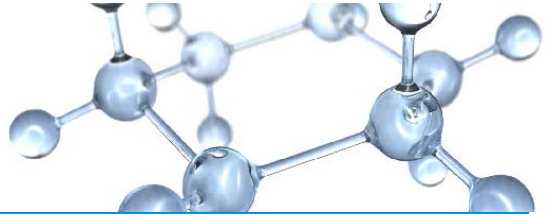
By Fuel

Quadrillion BTUs



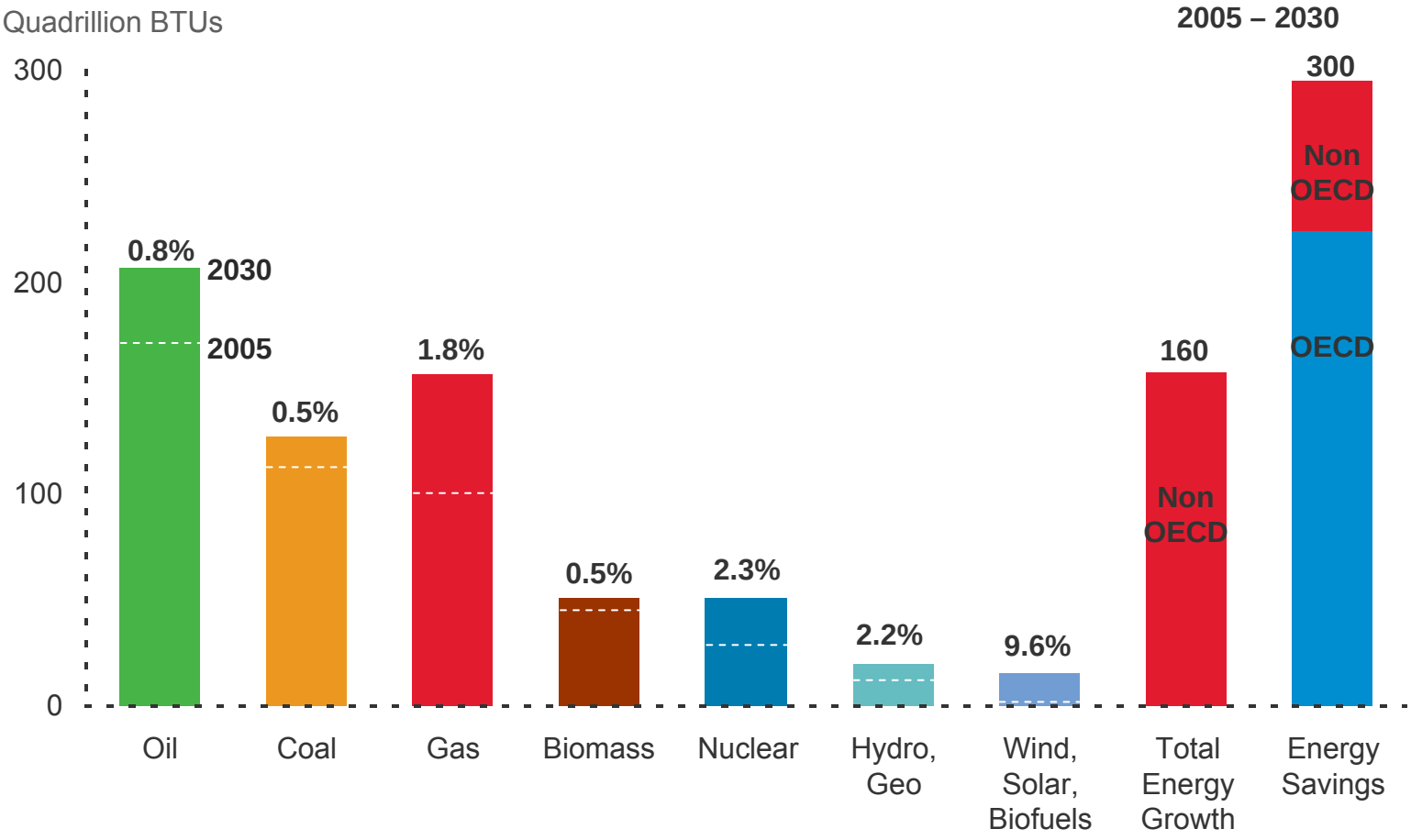
ExxonMobil
Taking on the world's toughest energy challenges.™

Global Energy Demand and Supply



Demand and Supply

Quadrillion BTUs



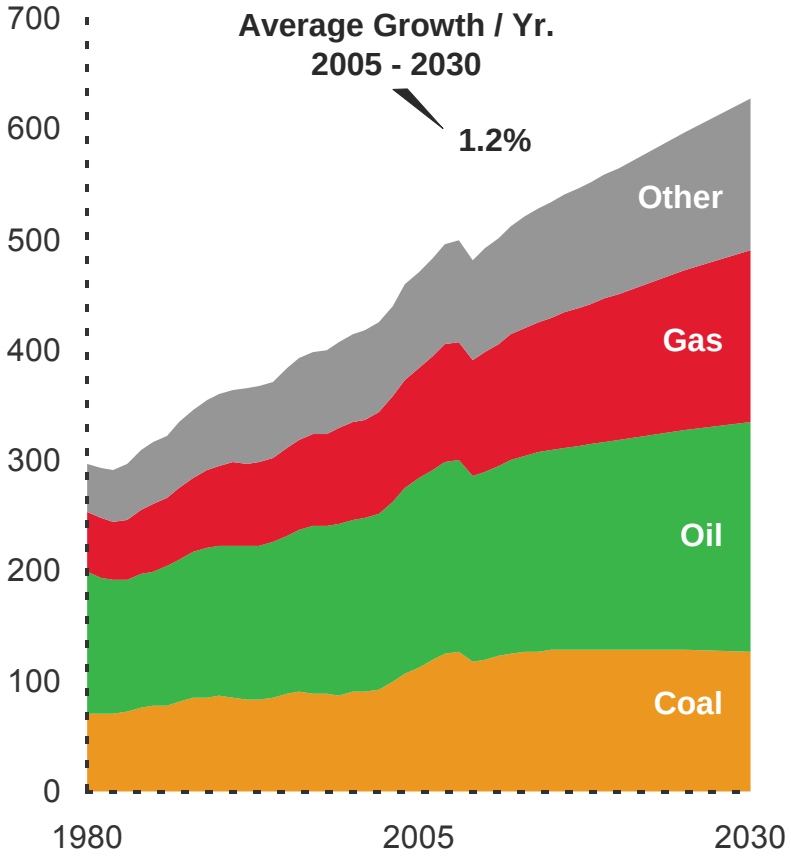
ExxonMobil

Taking on the world's toughest energy challenges.™

Global Energy Demand & CO_2 Emissions

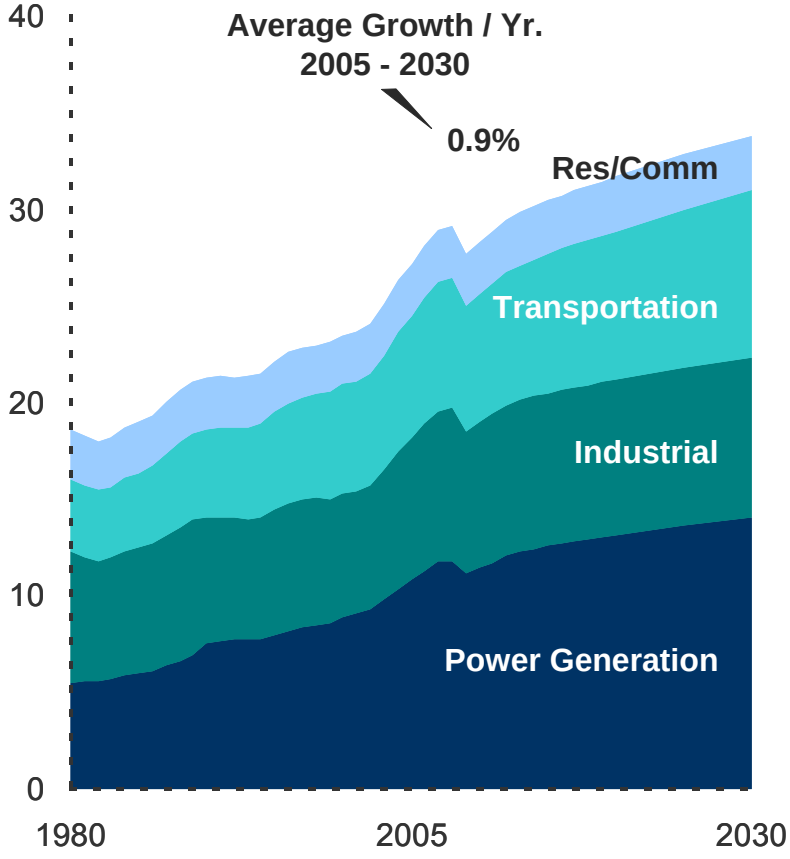
Demand

Quadrillion BTUs



CO_2 Emissions

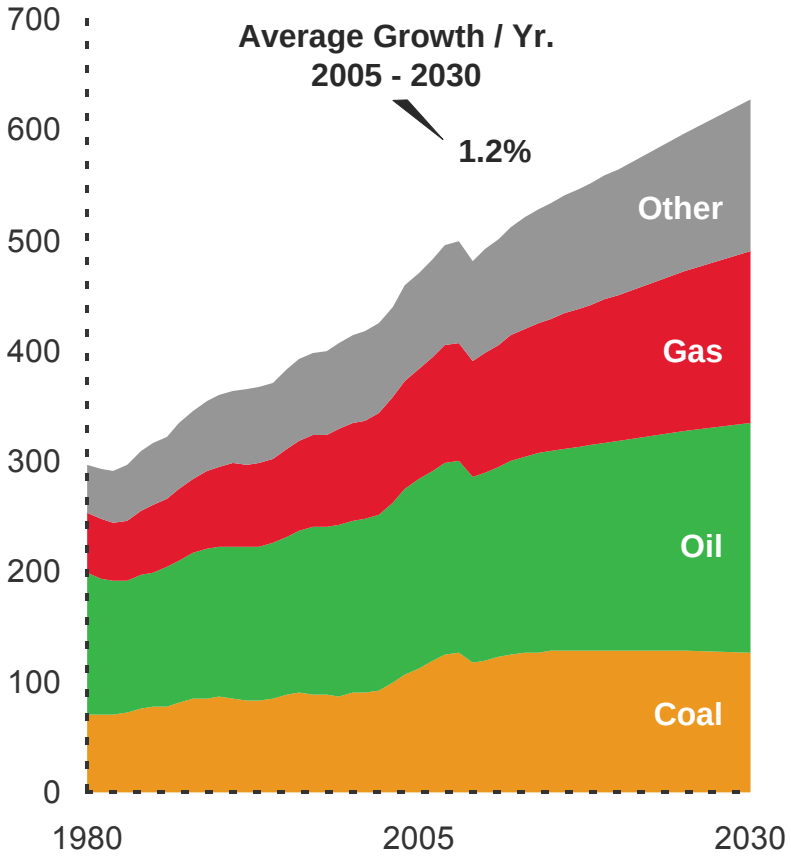
Billion Tons



Global Energy Demand & CO_2 Emissions

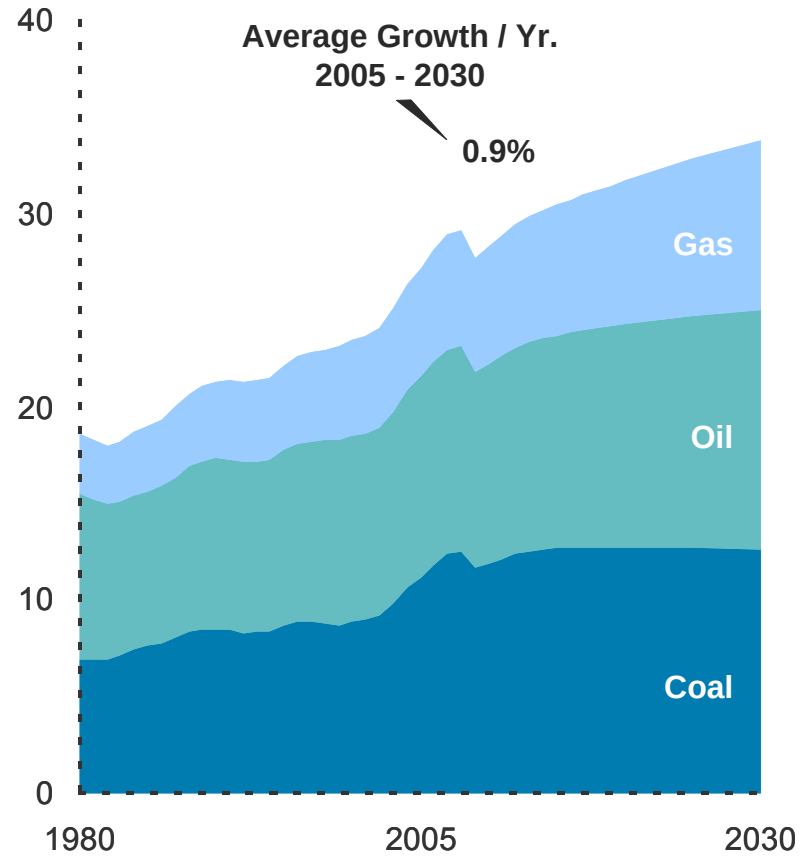
Demand

Quadrillion BTUs



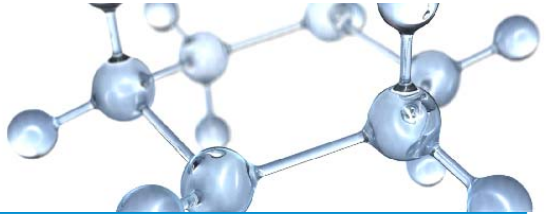
CO_2 Emissions

Billion Tons



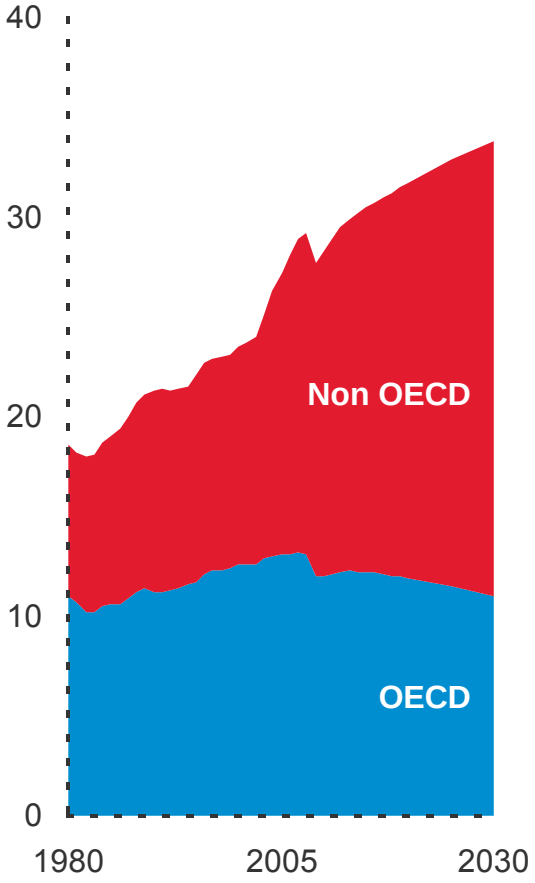
ExxonMobil
Taking on the world's toughest energy challenges.™

CO_2 Emissions



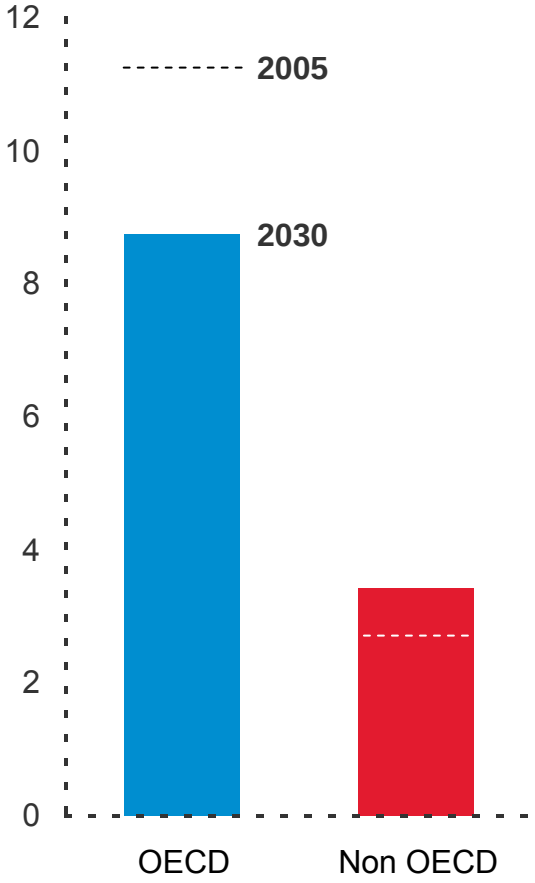
CO_2 Emissions

Billion Tons



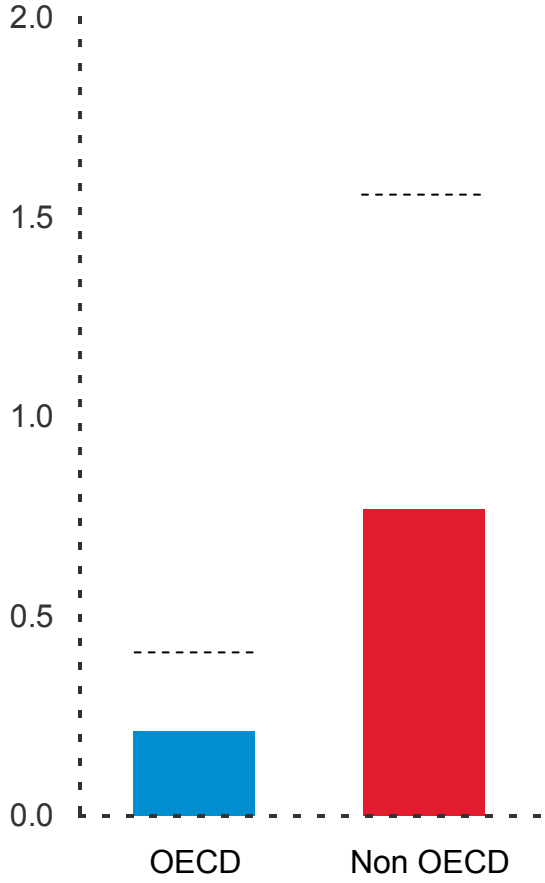
Emissions per Capita

Tons / Person

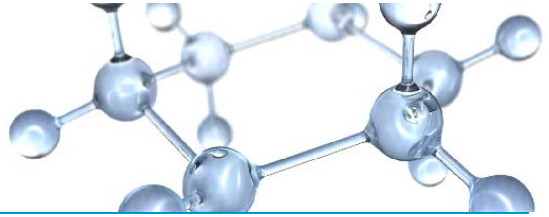


Emissions per GDP

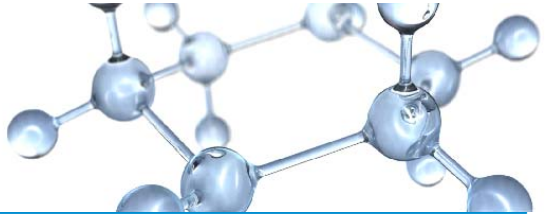
Tons / 2005$ k GDP



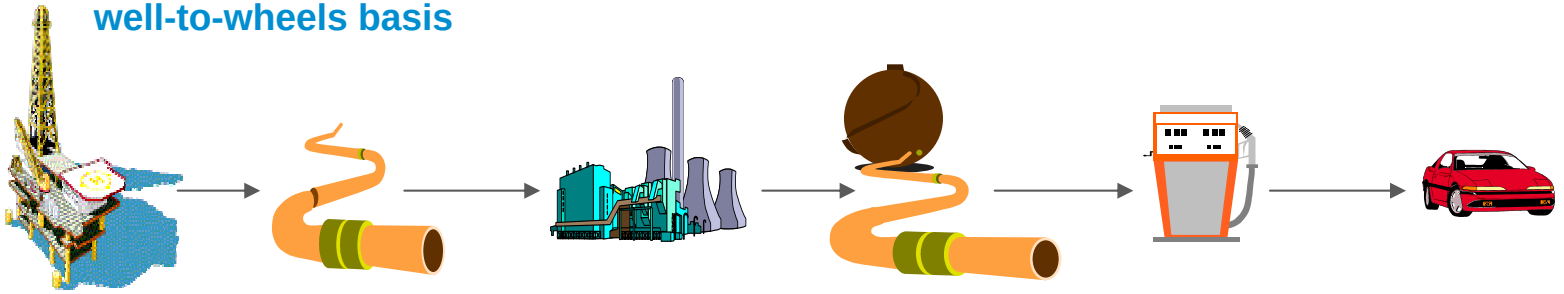
Integrated Energy Solutions



technologies for light duty vehicles



well-to-wheels basis



crude recovery → *crude transportation* → *crude refining to products* → *product storage & transportation* → *retail site* → *gasoline vehicle*

production of fuel
20% GHG/mile

Consumers' use of fuel
80% GHG/mile

technologies for fuel production

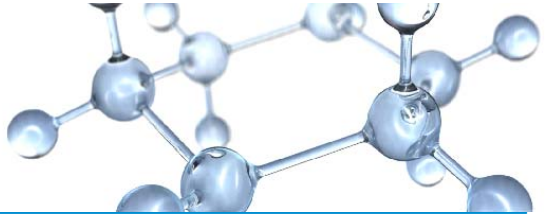
shorter-term
- energy efficiency
- flare reduction
- cogeneration

longer-term
- second generation bio-fuels
- carbon capture and storage (CCS)

technologies for consumers' use of fuel

Source: U.S. Basis - WTW Study, Argonne National Lab, 2005

shorter-term technologies



energy efficiency

improving energy efficiency in our facilities

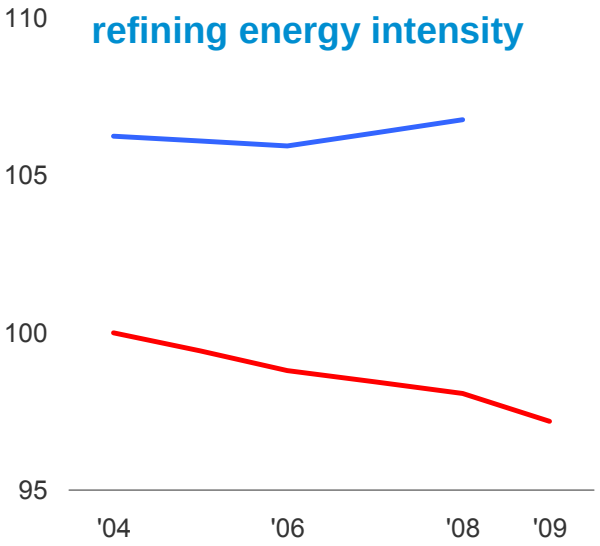
flare reduction

reduction of routine flaring of natural gas that is a byproduct of oil production

cogeneration

heat generated during generation of electricity is captured and used for other purposes

refining energy intensity

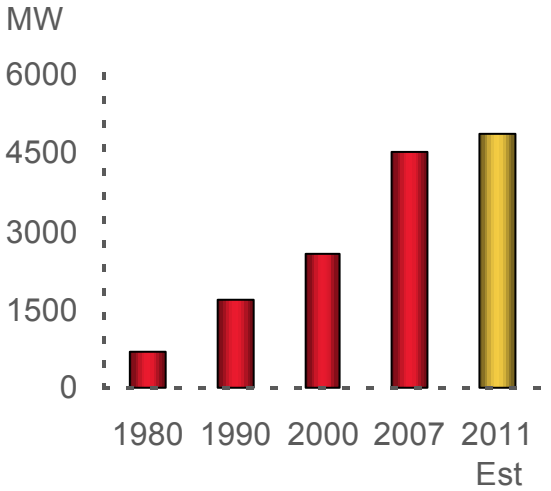


Source: Solomon Associates fuels refining benchmarking data through '08 available on even years;

ExxonMobil estimate for '09; Data indexed to ExxonMobil ('04)

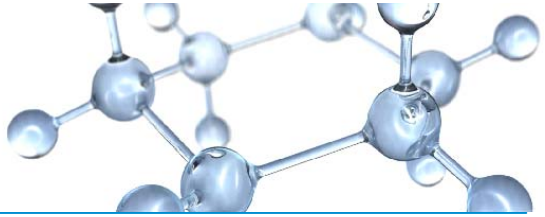
Beaumont Cogen
Texas, USA

cogeneration capacity in which ExxonMobil has an interest

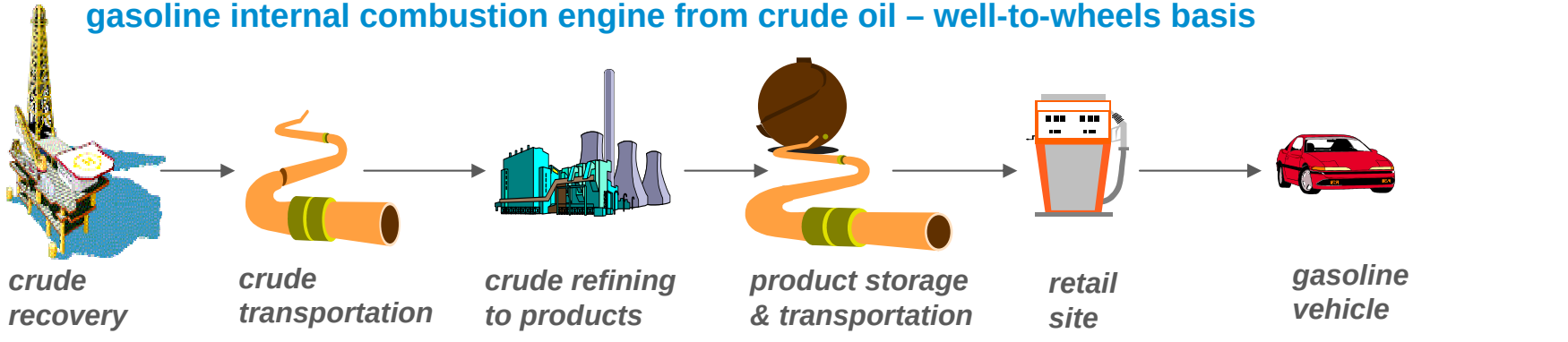


ExxonMobil
Taking on the world's toughest energy challenges.™

technologies for light duty vehicles



gasoline internal combustion engine from crude oil – well-to-wheels basis



technologies for fuel production

shorter-term
- energy efficiency
- flare reduction
- cogeneration

longer-term
- second generation bio-fuels
- Carbon Capture and Storage (CCS)

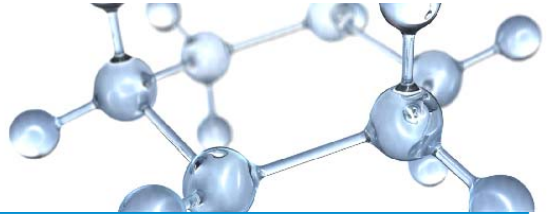
technologies for consumers' use of fuel

shorter-term
- conventional vehicle technology improvements
  - engines (e.g. adv. lubricants); efficient transmissions
  - others (e.g. tire liners, low weight plastics)
- advanced vehicles
  - hybrid (e.g. lithium ion battery materials)
  - advanced diesel

longer-term
- breakthrough vehicles
  - "HCCI" or "CAI"; fuel cell (e.g. on-board H_2 generator)
  - plug-in hybrid and EV (e.g. lithium ion battery materials)

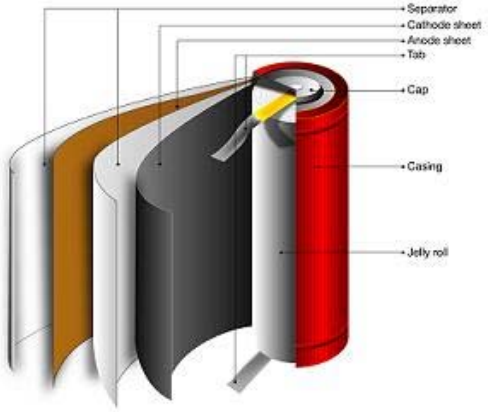
Source: U.S. Basis - WTW Study, Argonne National Lab, 2005

improving consumers' use of energy



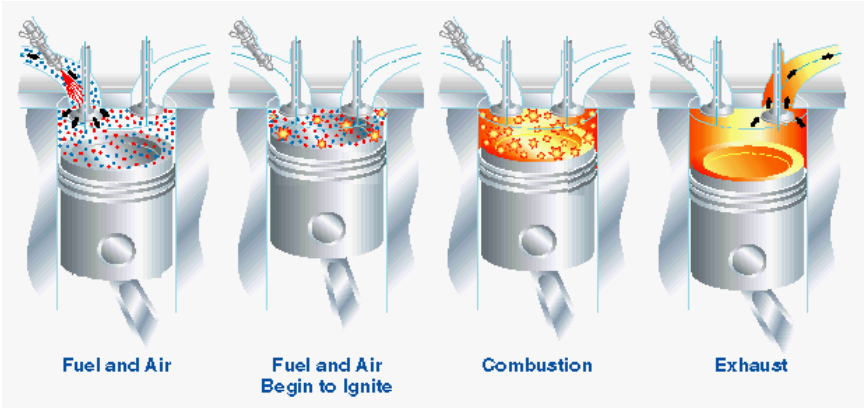
lithium-ion battery materials*

new separator technology for lighter and safer hybrid and electric vehicle batteries



on-board hydrogen generator for fuel cell vehicles

converts hydrocarbon fuels into hydrogen to power a fuel cell – all on-board the vehicle



advanced engines and fuels research

potential for improved fuel economy vs. gasoline engines

Since 4Q'09 Lithium Ion Battery Separator films are produced and marketed by Toray Tonen Specialty Separator Godo Kaisha, a joint venture in which ExxonMobil has a 25% interest.

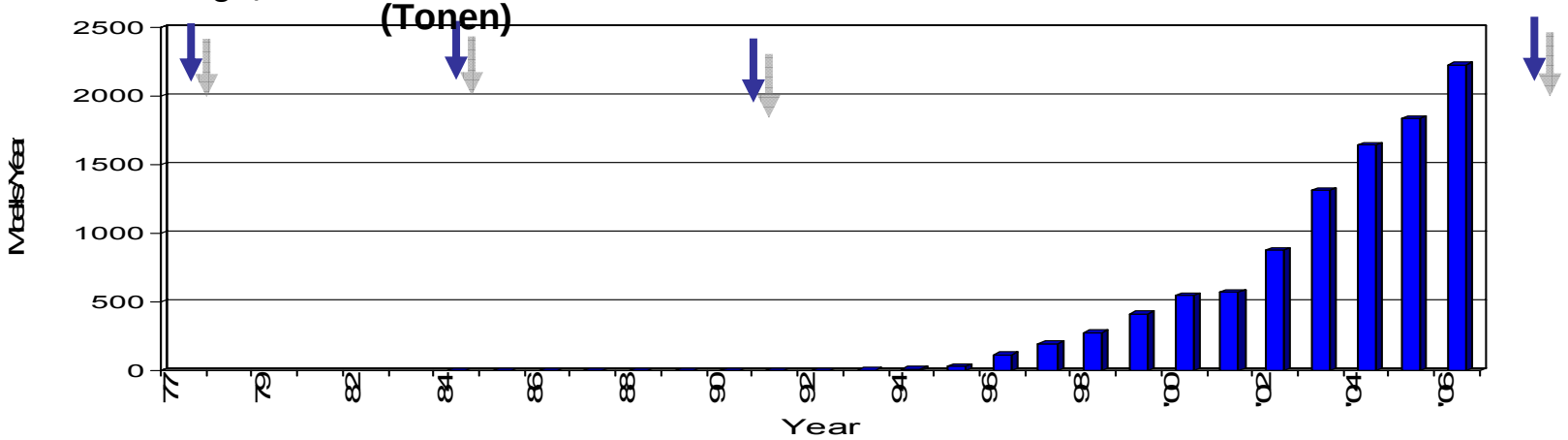
history of Li-ion batteries

Early Exxon Li-ion Battery at EV show Chicago, '77

Invention of microporous PE separator by Exxon and Mobil Affiliate (Tonen)

Tonen Separator used in world's first consumer LIB

Tonen - Toray JV formed



Applications: Cellphone, laptop, camcorder, digital camera, power tool, *e*bikes,…

1 Ah

14 Ah

70 Ah

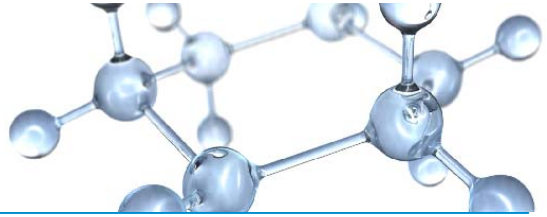
220 Ah

4000+ Ah

Electrovaya's Maya-300

Since 4Q'09 Lithium Ion Battery Separator films are produced and marketed by Toray Tonen Specialty Separator Godo Kaisha, a joint venture in which ExxonMobil has a 25% interest.

Integrated Energy Solutions

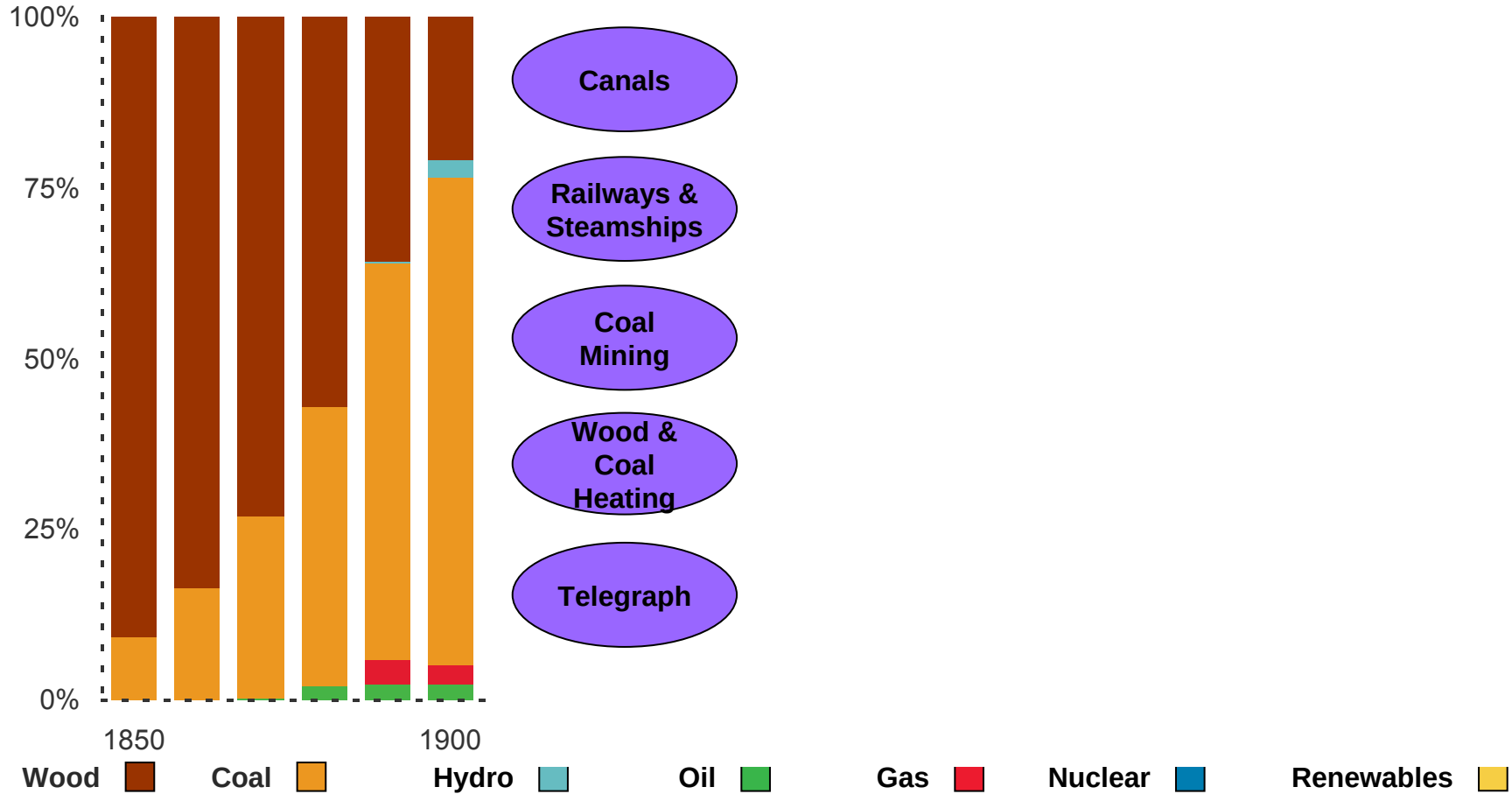


ExxonMobil
Taking on the world's toughest energy challenges.™

Transition to Modern Energy / Technology

US Energy Demand

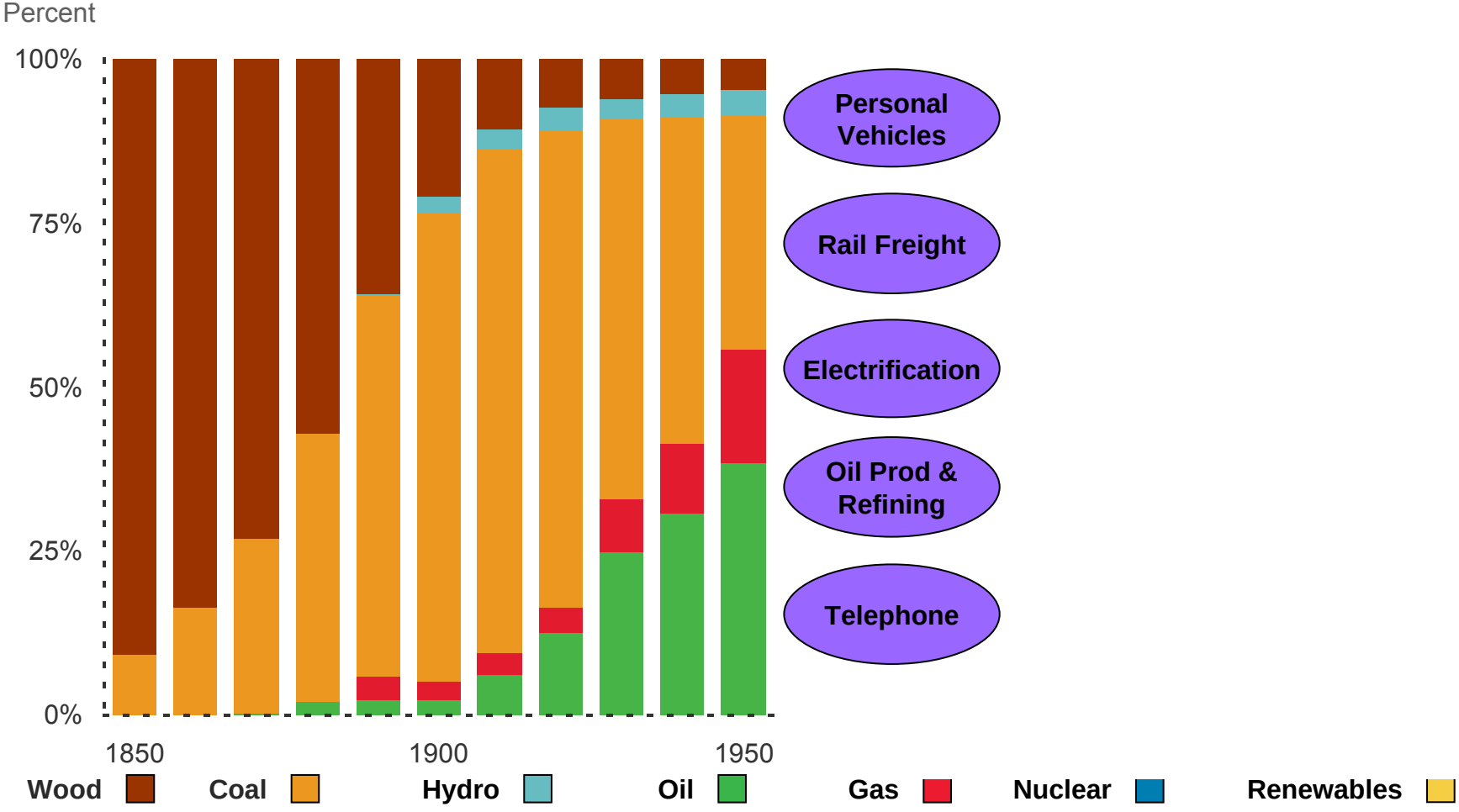
Percent



Energy Information Agency

Transition to Modern Energy / Technology

US Energy Demand

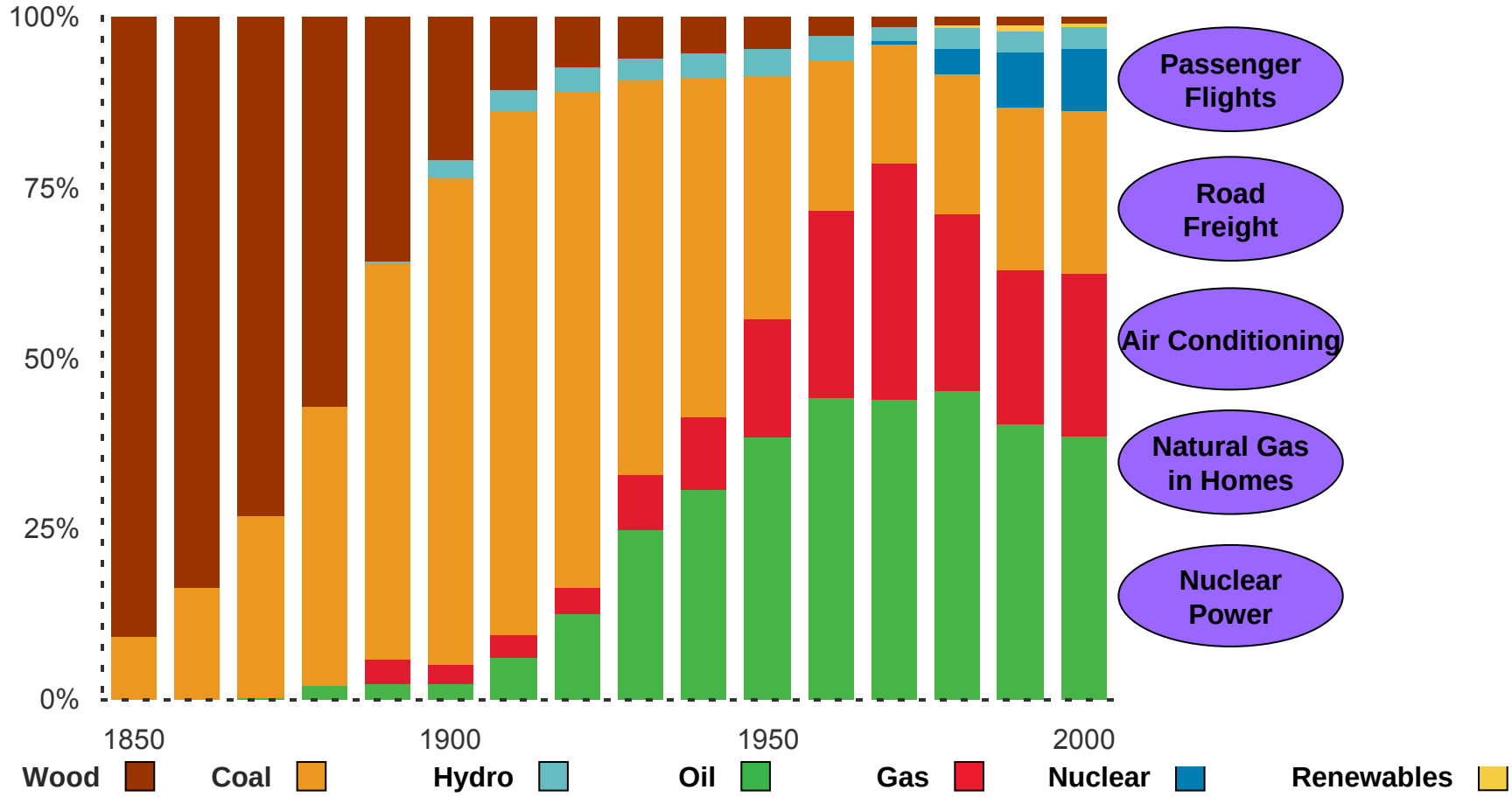


Energy Information Agency

Transition to Modern Energy / Technology

US Energy Demand

Percent

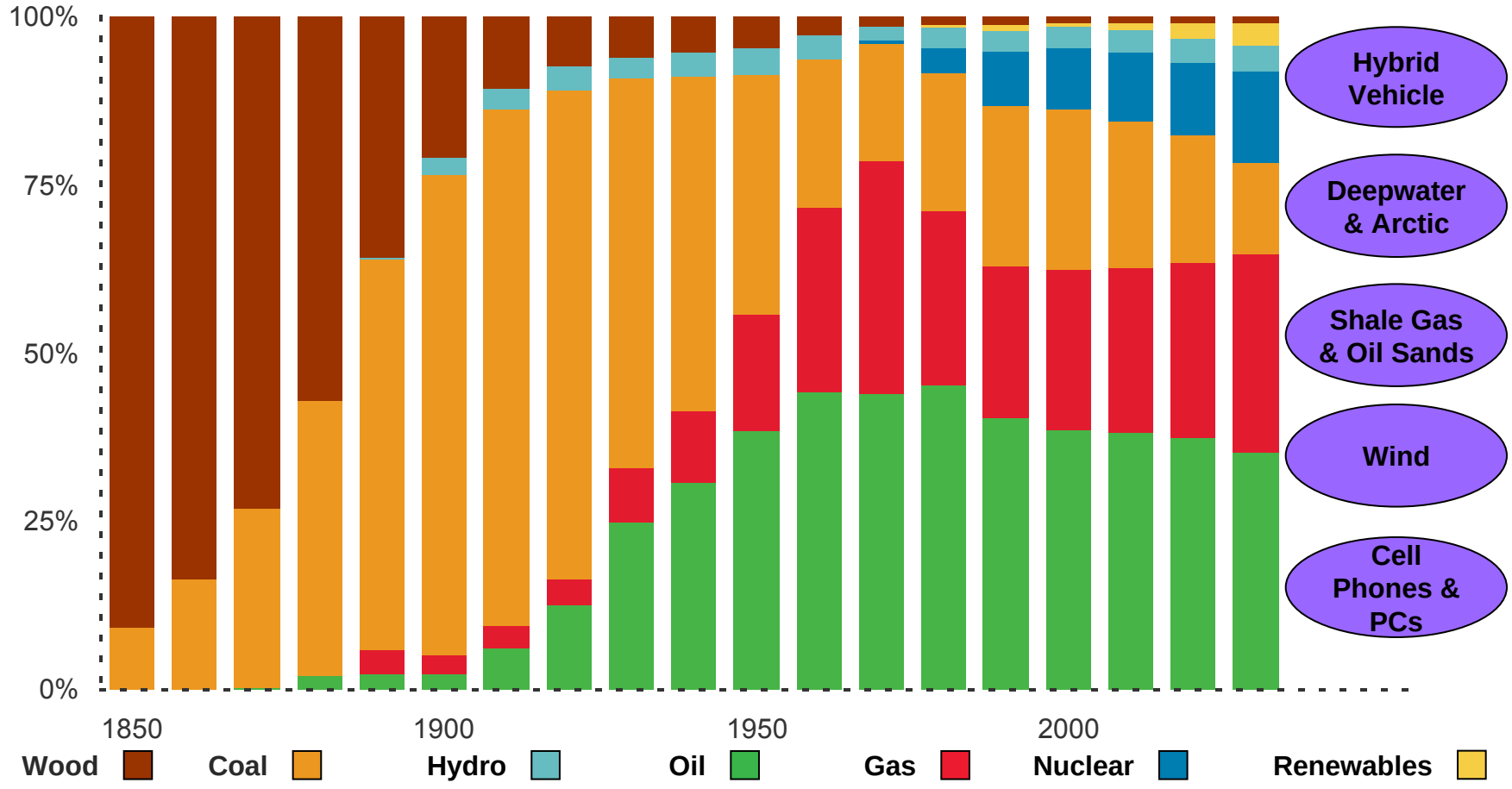


Energy Information Agency

Transition to Modern Energy / Technology

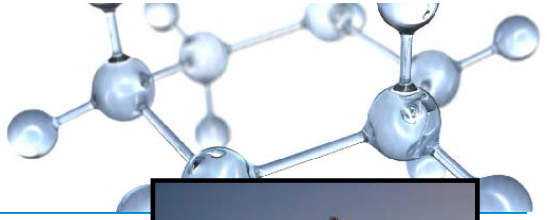
US Energy Demand

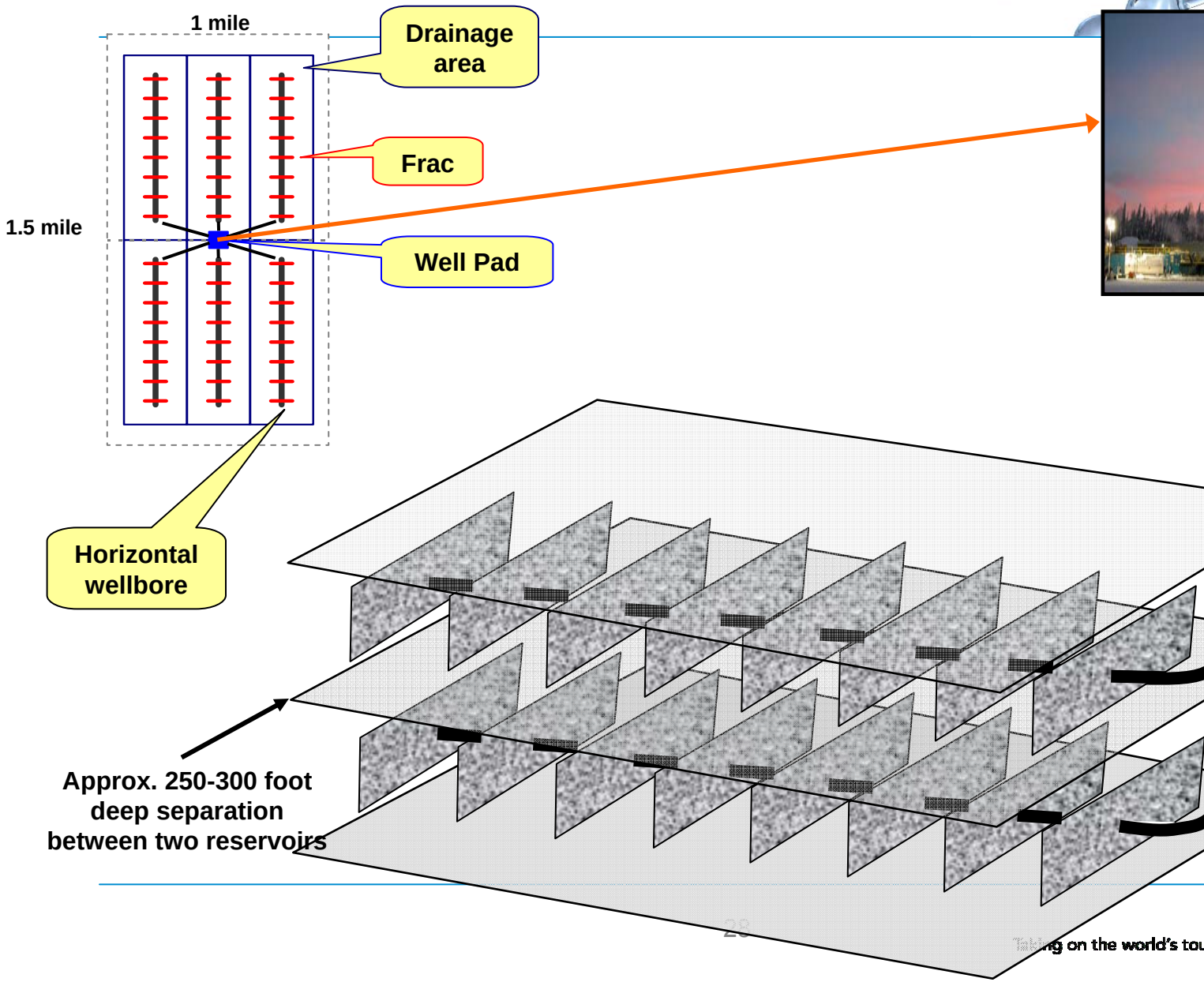
Percent



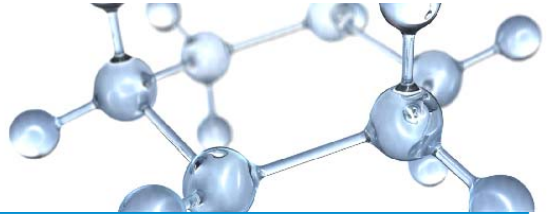
Energy Information Agency

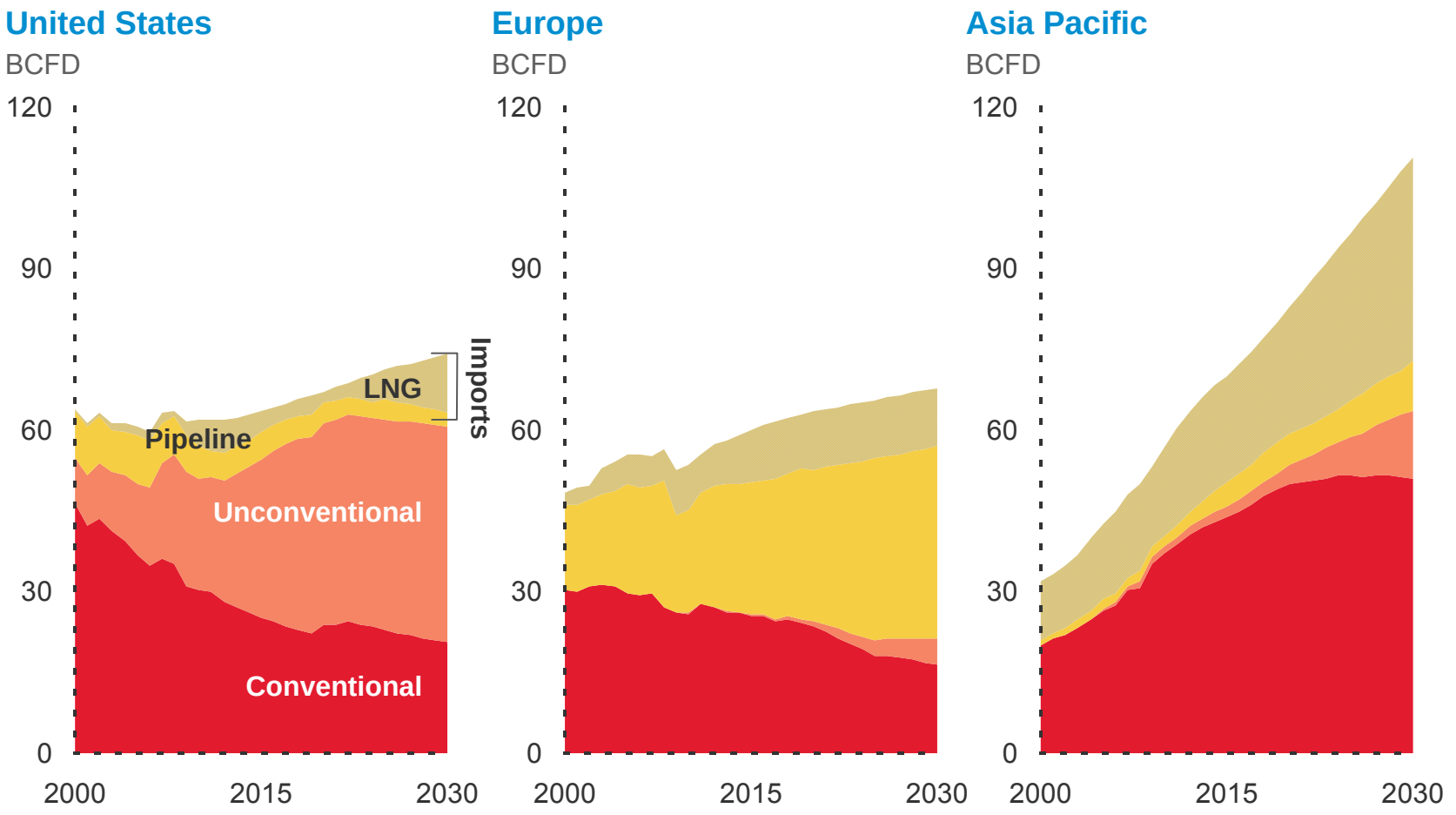
Multi-Zone, Multi-Lateral Production





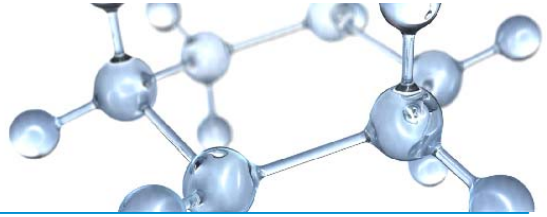
Gas Supply and Demand Balance

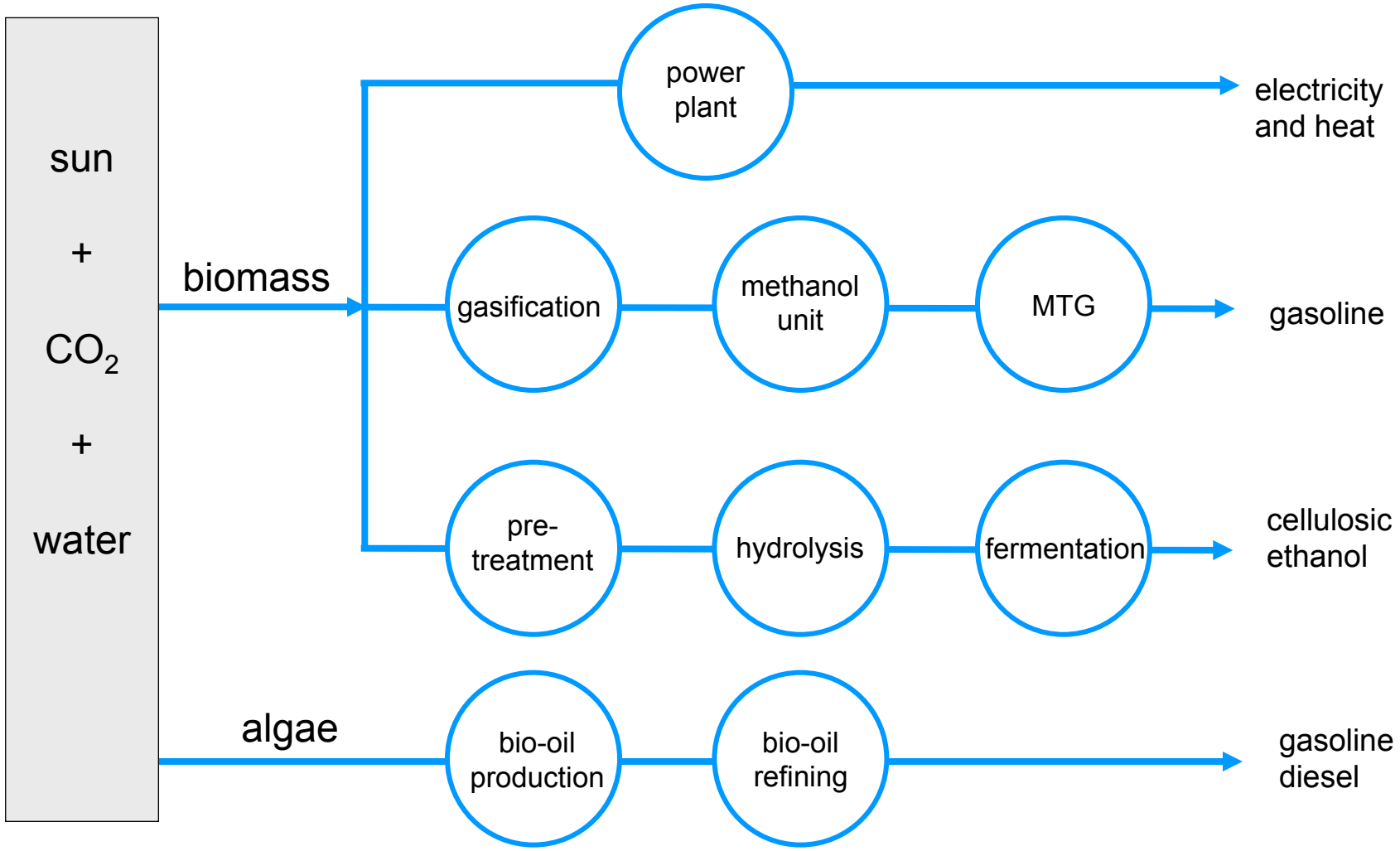




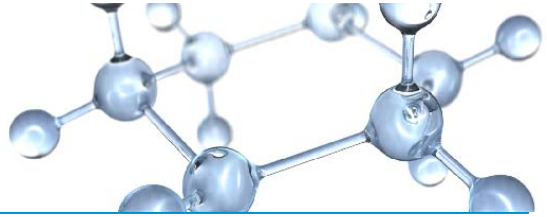
LNG: Liquefied Natural Gas

Many non-food bio-energy pathways emerging





Algae-based biofuels

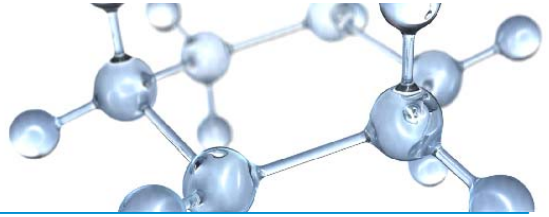


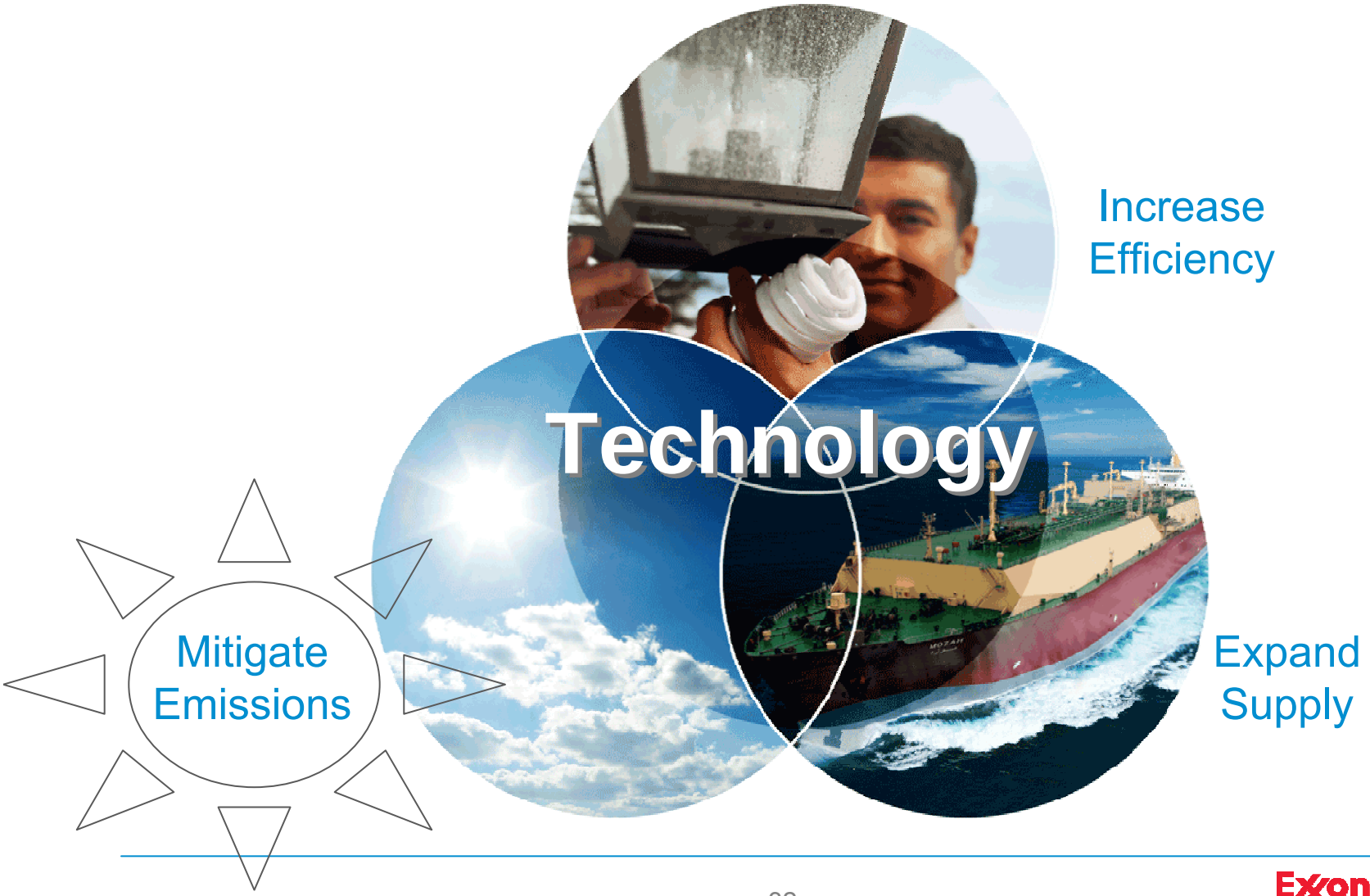
- ExxonMobil alliance with Synthetic Genomics Inc
  - focus on development of advanced biofuels from photosynthetic algae
  - complements ExxonMobil's ongoing efforts to advance breakthrough technologies to meet the world's energy challenges

Sunlight | **Carbon Dioxide** | **Water** | **Algae** | **More Algae Containing Hydrocarbons** | **Oxygen**

- benefits of using algae for biofuels production:
  - can be grown using land and water unsuitable for food production
  - potentially yield greater volumes of biofuels per acre than other biofuel sources
  - could be used to manufacture biofuels similar to today's transportation fuels
  - growing algae consume CO_2; algae-based biofuels could provide GHG mitigation benefits versus conventional fuels

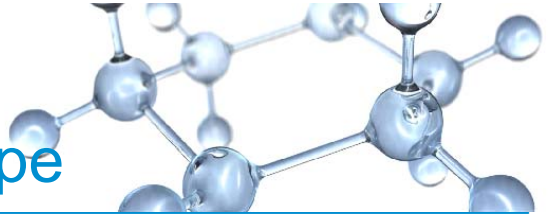
Integrated Energy Solutions

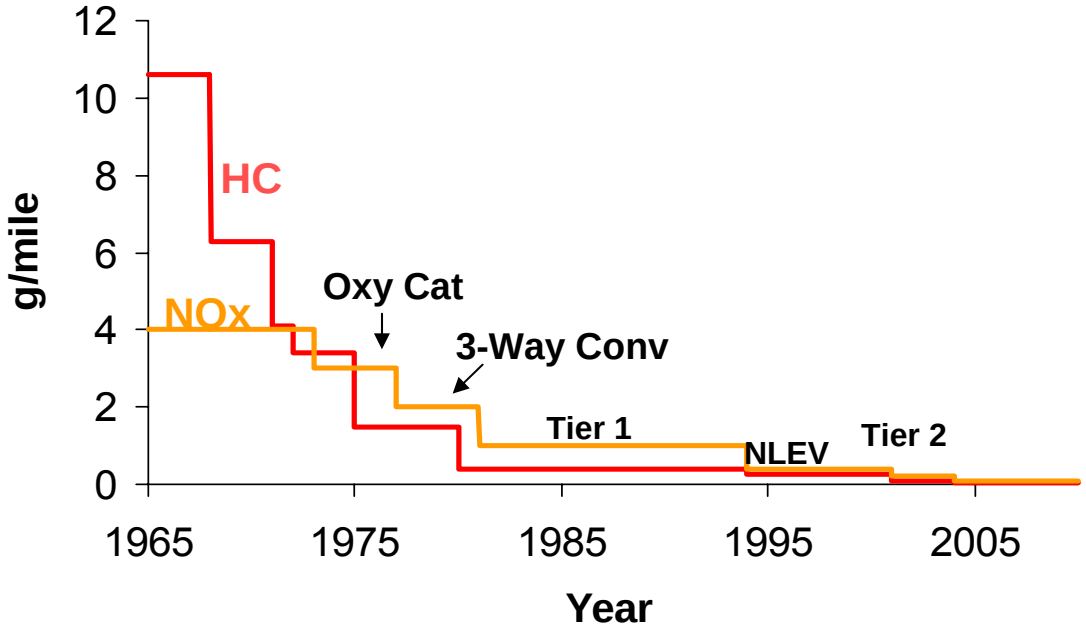




ExxonMobil
Taking on the world's toughest energy challenges.™

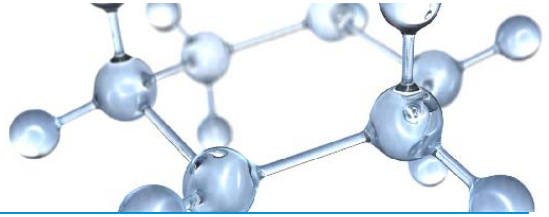
Criterion Emissions from Vehicle Tailpipe

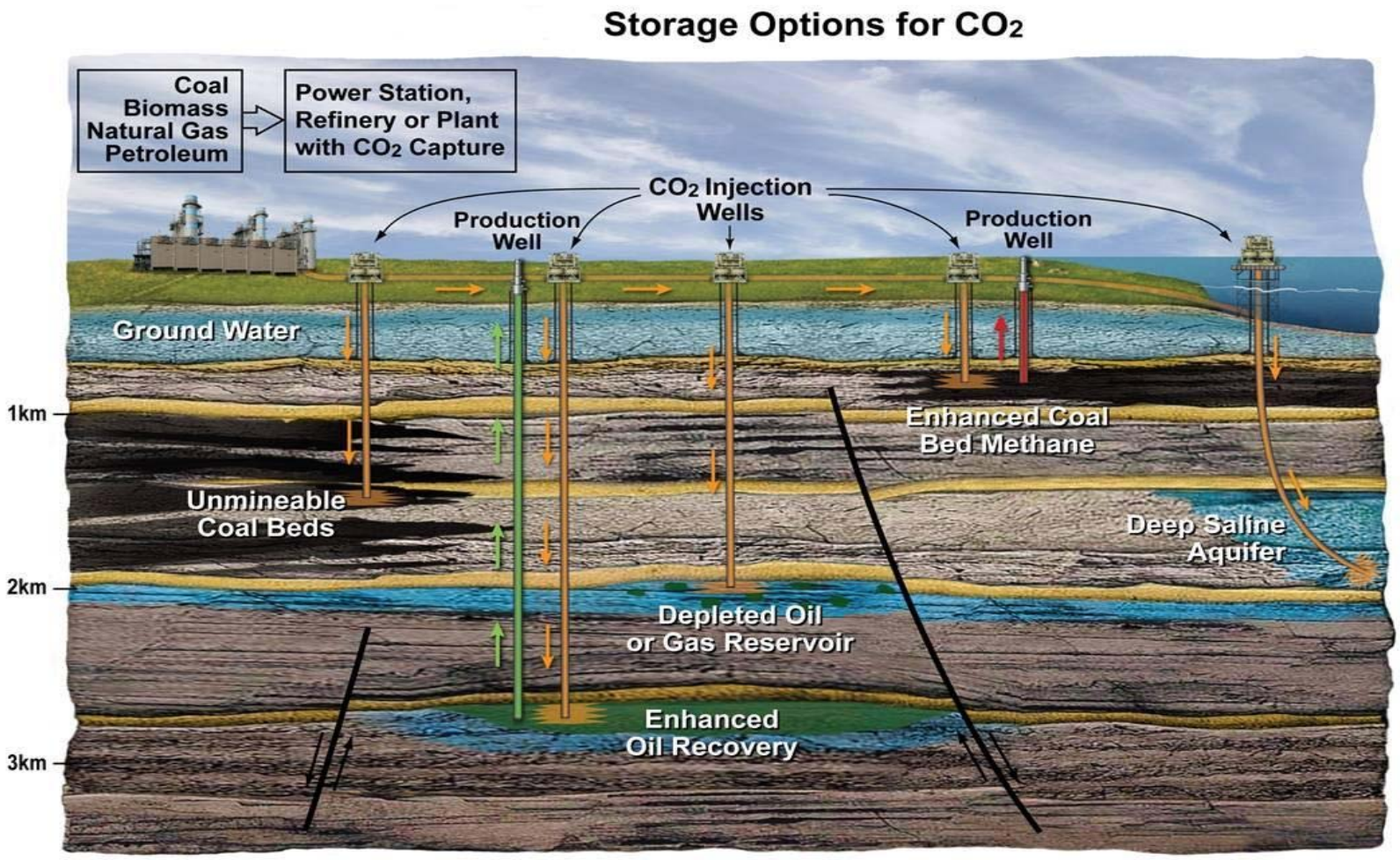




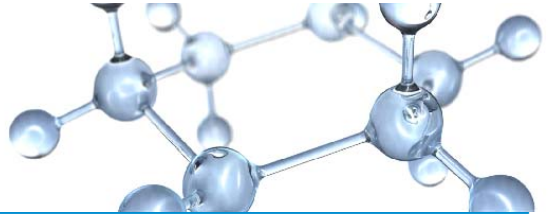
- Technology has enabled significant reductions in tail-pipe emissions to improve air quality
- Contributions from engine technologies, after-treatment systems, in-use monitoring (Inspection and Maintenance, on-board diagnostics) and fuels

CCS





CCS Segments and Costs

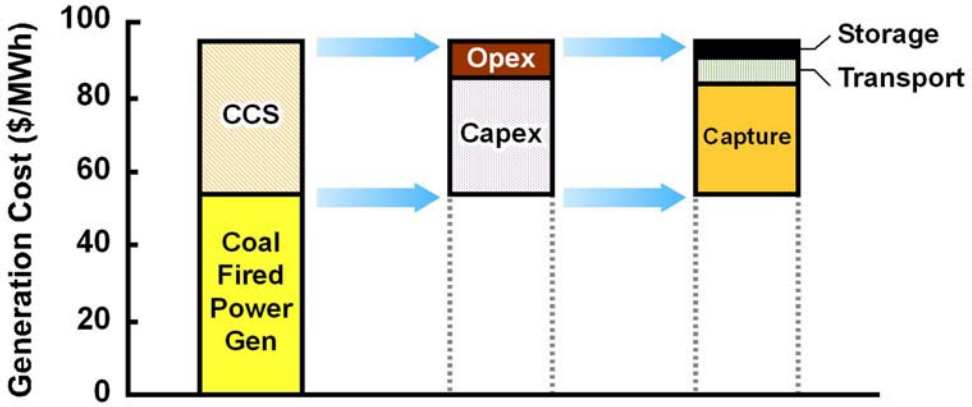


CCS Cost Drivers

- Size of CO_2 source
- CO_2 concentration
- CO_2 pressure
- Maturity of technology
- Proximity to and quality of storage

IHS CERA

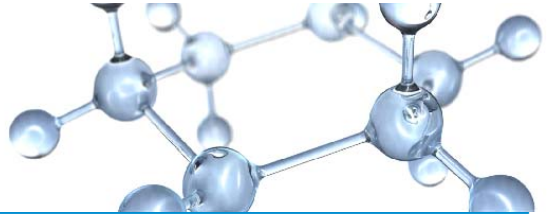
DISTRIBUTION OF CCS GENERATION COSTS (coal)



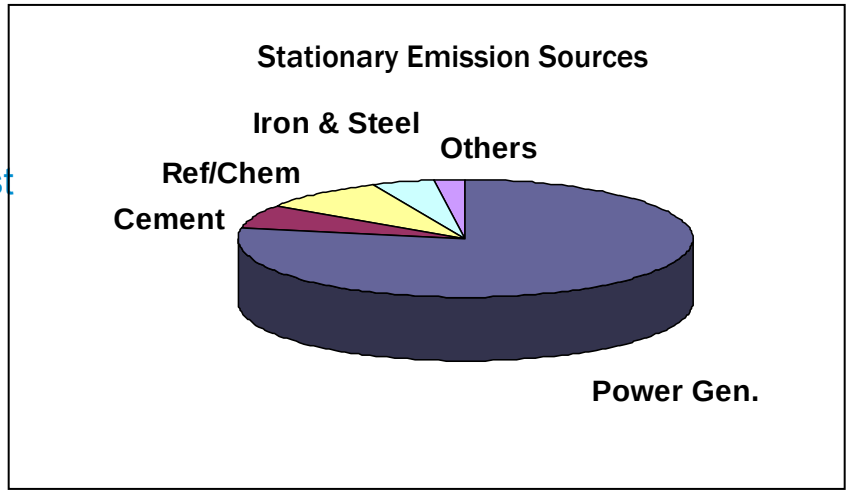
2009 Costs ($ per ton CO2 stored)	*Capture + Compression*	*Transportation*	*Storage*	*Total Cost*
Low Cost	Gas processing: $10–$25	At site: $0	EOR or EGR: ($10–$30)	($20)–$15
Medium Cost	Coal power plants: $60–$120	30–200 miles: $2–$10	Depleted oil/gas field: $5–$10	$70–$140
High Cost	Refining, air: $100–$1,000+	>500 miles: $15–$25	Offshore saline: $20–$30	$140+ Likely >$500

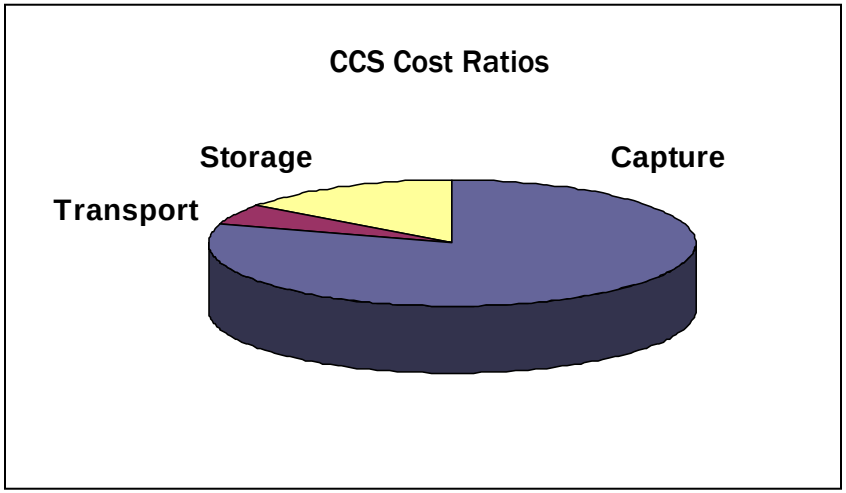
From CERA – Fueling North America's Energy Future – 2010
Data sources: IHS CERA, US Department of Energy, National Energy Technology Laboratory, and industry sources.
00112-25

challenges in commercializing CCS



- large scale demonstration of integrated component technologies
- technology improvements to reduce capital cost and energy intensity
- sound legal and regulatory framework
  - stable economic basis
  - property rights/access
  - long term site responsibility
- recognition of scale
  - rivals existing oil and gas production infrastructure.
- LaBarge experience illustrates the challenges, opportunities, and progress
  - Two decades of experience in using geological CO2 (pure or for NG separation)





experience with CCS technologies

Shute Creek, Wyoming

Gas Composition

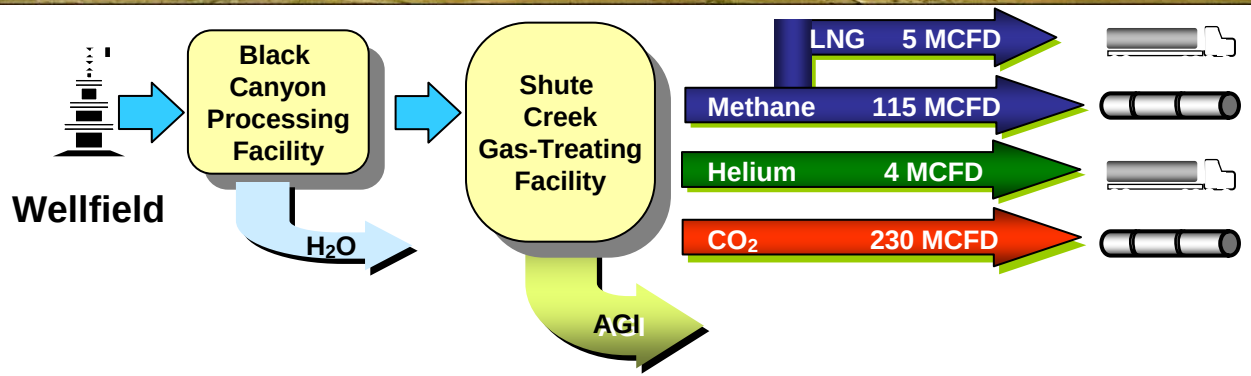
65% Carbon dioxide

22% Methane

7.4% Nitrogen

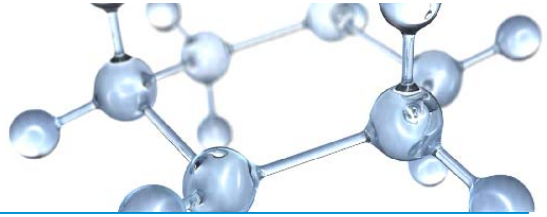
5.0% Hydrogen Sulfide

0.6% Helium



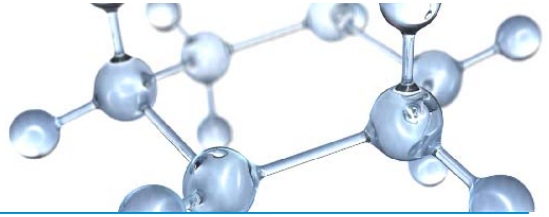
ExxonMobil
Taking on the world's toughest energy challenges.™

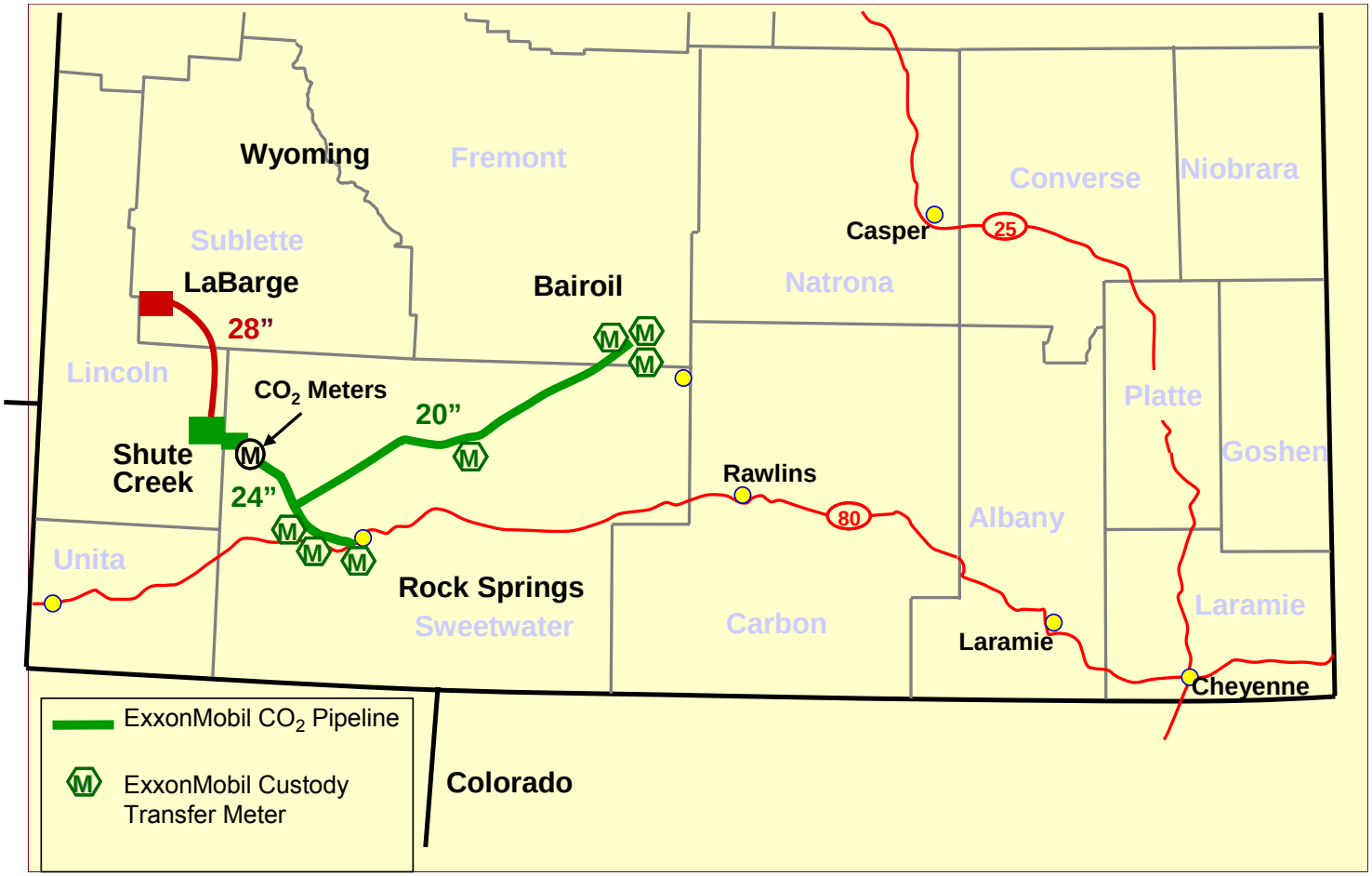
LaBarge operations



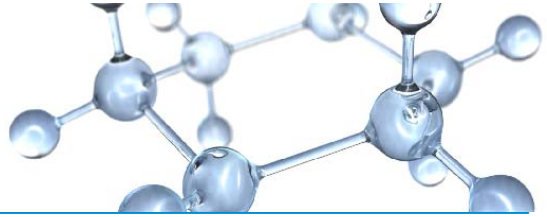
- history
  - First well tested by Mobil 1963
  - First well tested by Exxon (Humble) 1969
  - Delineation wells drilled by Exxon 1981
  - Plant site construction began 1984
  - First production 1986
- LaBarge project unique features
  - Lowest hydrocarbon gas commercially produced in industry
  - First and largest CO_2 sales system in the Rockies
  - Largest gas sweetening plant in the world
  - Largest helium recovery plant in the world (25-30% of world supply)
  - Largest longest sour gas pipeline in the world
  - Largest sour gas injection facility in the world

carbon dioxide pipeline system



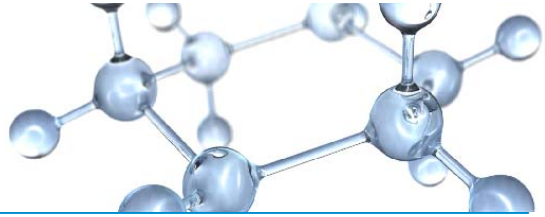


CO_2 management at LaBarge



- CO_2 sales for EOR began with plant start-up in 1986
  - current capacity 230 Mcfd
  - post expansion capacity 340 Mcfd (mid 2010)
- CO_2 Injection with sour gas 25 Mcfd
- vast majority of CO_2 sales utilized for EOR
  - demonstrates IEA "early opportunity" model for CCS – Capture and EOR
    - current sales capacity ~ 5 Mt/yr (equivalent to 1.1 M vehicles)
    - post expansion sales ~ 7 Mt/yr (equivalent to 1.6 M vehicles)
- Co-gen facility reduces CO_2 emissions by ~ 50 % compared to purchased power
  - ExxonMobil patented low BTU combustion technology
- Controlled Freeze Zone™ commercial demonstration

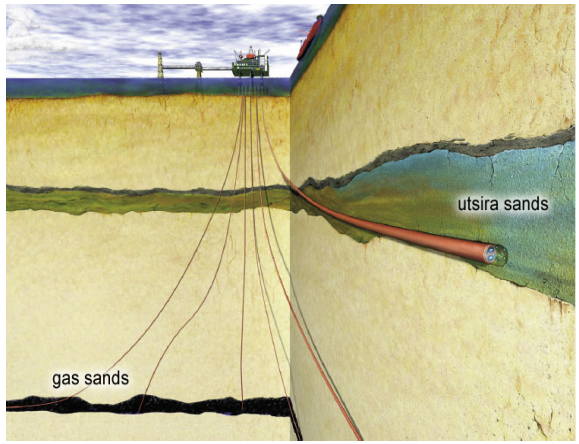
CCS experiences and technologies



CCS experience

10+ yrs experience with CCS in deep saline reservoir at Sleipner

30 yrs experience in CO2 EOR



O. Kaarstad, Statoil IEA 2004

CFZ Pilot Unit,, Clear Lake, TX

Technology Development

Controlled Freeze Zone (CFZ) demonstration in La Barge, WY

single step, lower cost separation of CO2 from natural gas

R&D Partnerships

CO2 REMOVE research monitoring verification

Carbon Capture & Sequestration Technologies @ MIT

UNIVERSITY OF WYOMING

Breakthrough Research

GCEP Global Climate & Energy Project STANFORD UNIVERSITY

Gulf Coast Carbon Center

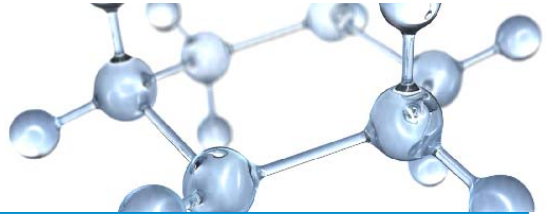
SWP Southwest Partnership CO2 Sequestration

GCCSI

SECARB Southeast Regional Carbon Sequestration Partnership

Georgia Tech

Integrated Energy Solutions



Now

- 6.7 billion people
- Global economic linkages
- Disparate living standards
- Enormous energy needs
- Environmental gains & concerns
- Growing technology use & focus

Increase Efficiency

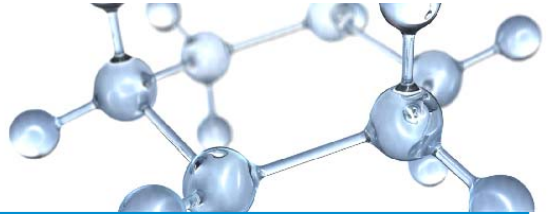
Expand Supply

Mitigate Emissions

2030

- 8 billion people
- Non OECD leads economic growth
- Less poverty; living standards improve
- Global energy needs up one-third
- Progress on environmental goals
- Significant advances in technology

Integrated Energy Solutions



Increase Efficiency

Mitigate Emissions

Expand Supply